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IRON AND STEEL ENGINEER

JANUARY • 1941

VOL. XVIII NO. I

In This Issue

Modern Arc Furnace Design and Practice—by H. F. Walther, Assistant Melting Superintendent, Steel and Tube Division, Timken Roller Bearing Company, Canton, Ohio..... 22

Discussion: Modern Arc Furnace Design and Practice—Presented by L. V. Black and G. E. Stoltz..... 32

Soaking Pit Control—by M. J. Boho, Control Engineer, Hagan Corporation, Pittsburgh, Pennsylvania..... 34

Discussion: Soaking Pit Control—Presented by John R. Green, E. E. Callinan, W. T. Dean, F. D. Burne, M. J. Boho, and G. R. McDermott..... 42

Neutral Grounding in A-c. Systems for Steel Mills—by L. T. Rosenberg, Alternating-Current Engineeing Department, Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin..... 44

The Use of the Normal Curve in Problems of the Steel Industry—by H. Ziebolz, Vice-President, Askania Regulator Company, Chicago, Illinois..... 50

Developments in the Iron and Steel Industry During 1940—by W. H. Burr, Chairman Development Committee Report, A.I.S.E., and Electrical Superintendent, Lukens Steel Company, Coatesville, Pennsylvania..... 54

Steel Plant Maintenance Shops—by T. R. Moxley, General Master Mechanic, Wheeling Steel Corporation, Steubenville, Ohio 75

Discussion: Steel Plant Maintenance Shops—Presented by R. D. Wearne..... 82

Philadelphia District Section, A.I.S.E., Celebrates Twenty-Fifth Anniversary..... 83

President's Message..... 84

Newly Elected Officers and Board of Directors, A.I.S.E...... 86

National Committees, A.I.S.E...... 88

Latest Design and Equipment for the Industry..... 93

Items of Interest..... 104

Association District Section Activities..... 124

Index to Advertisers..... 17

Published Monthly by

ASSOCIATION OF IRON AND STEEL ENGINEERS

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879

Statements and opinions given in articles and papers appearing in "Iron and Steel Engineer" are the expressions of contributors, for which the Association of Iron and Steel Engineers assumes no responsibility.

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Single Copy Foreign Prepaid $2.00 Single Copy $1.50

Subscription price in U. S. & Canada.....$ 7.50 per year

Subscription price in foreign countries.....$10.00 per year

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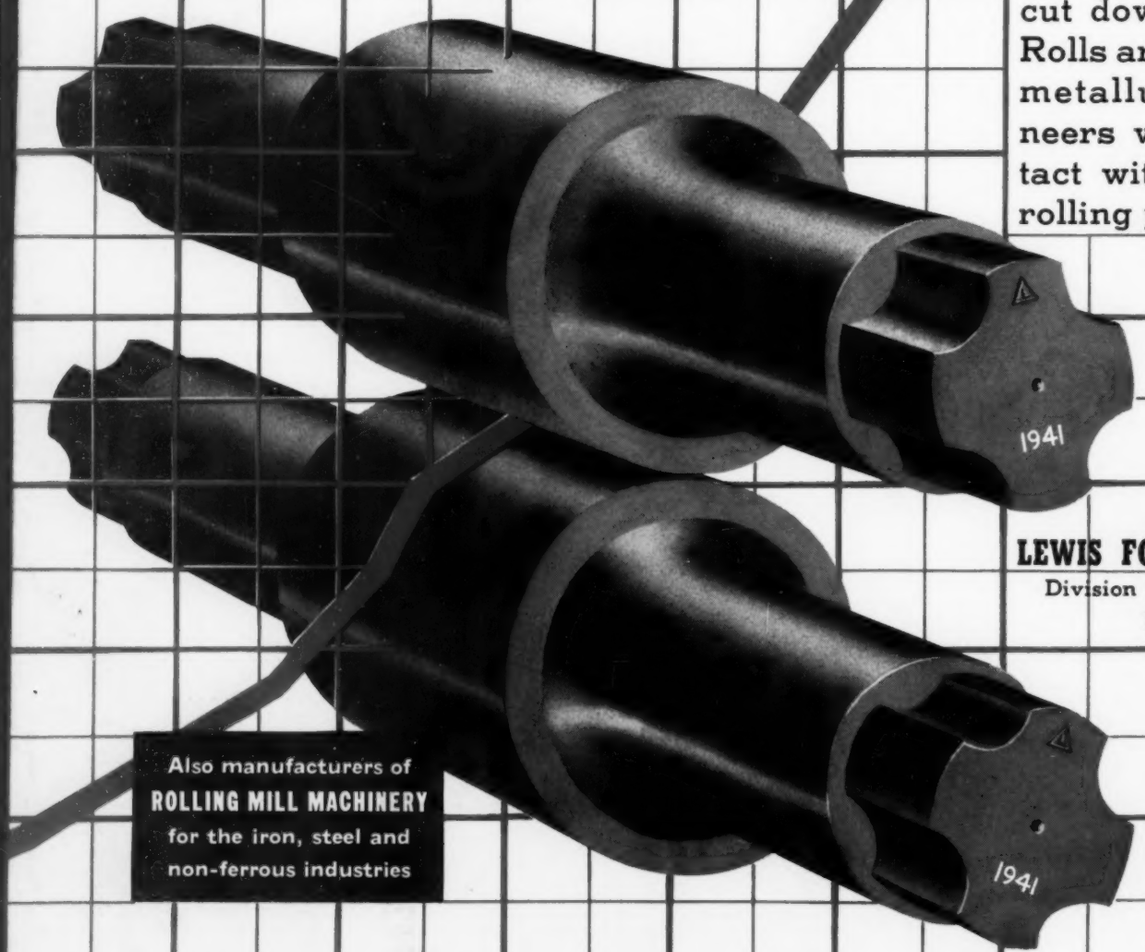

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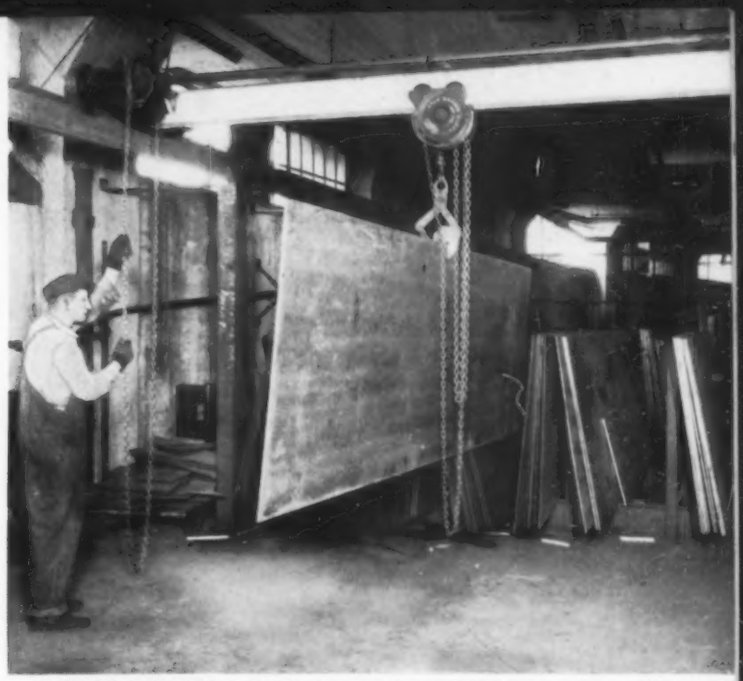

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MODERN ARC FURNACE
Design and Practice

By H. F. Walther

Assistant Melting Superintendent

TIMKEN ROLLER BEARING CO.

STEEL & TUBE DIVISION

CANTON, OHIO

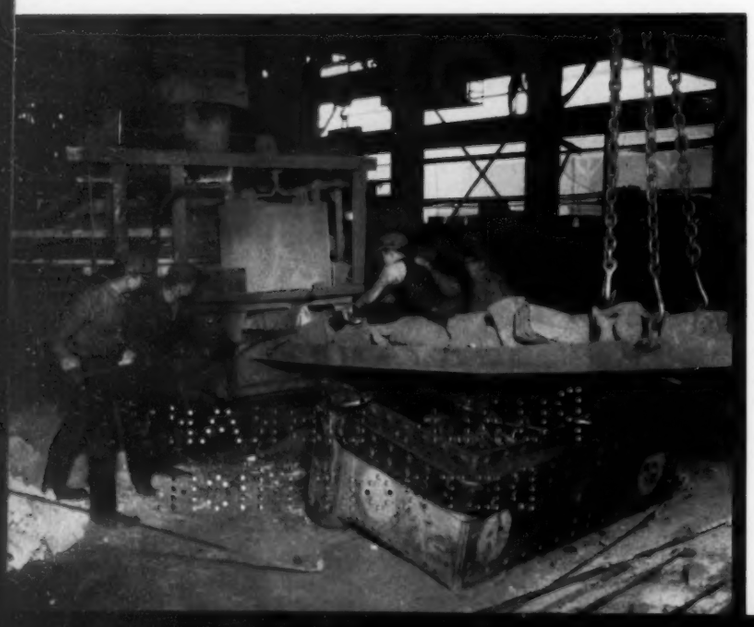
Presented before A. S. I. E. ANNUAL CONVENTION, Chicago, Illinois, September 24-27, 1940

▲ THE development of the electric arc furnace as a melting unit, once regarded as a scientific curiosity, has evolved to its present state of perfection by the combined weight of a sound therory, metallurgical progress and inventive genius.

Sir William Siemens, in 1880, laid the theoretical foundation by showing that an electric arc could be utilized to melt materials in a contracted space and also permit reactions at a controlled high temperature. Since dependable electric power generating facilities were not available, it was not until 1898 that any real effort was made to apply this process to industrial use, when Stassano, in Rome, invented a horizontal furnace with the indirect arc principle for the reduction of iron ore.

In 1899, Dr. Paul Heroult of France made use of the direct arc principle by producing ferro-chromium in an open top furnace. In attempting to produce steel in this furnace it was soon found out that a roof was necessary for efficient operation. This furnace then became in principle the basic design for practically all direct arc melting furnaces as we know them today, with the addition of modern improvements associated with technological progress.

FIGURE 1—This early six ton furnace was of squat design, with semi-automatic power regulation and hand charging.



The electric furnace was of European development and it was not until 1905 that the first furnace in North America was installed by the Canadian government at Sault Ste. Marie, under the direction of Dr. Heroult, for the reduction of iron ore. In 1906 the first furnace in the United States was installed in the plant of the Halcomb Steel Company at Syracuse, N. Y. This furnace was of 6 tons capacity and since there was no source of large electrodes available it was also necessary for them to install an amorphous carbon plant to supply the furnace.

In 1909–10 the United States Steel Corporation installed two 15 ton furnaces which were the largest yet built, to produce electric steel on a tonnage basis. During this period the crucible process was being supplanted by the electric furnace in a number of shops for the manufacture of tool steels and related products.

Because of the demand for high quality steel during the world war more emphasis was placed on the electric furnace as a producing medium, and installations were many. Since that time there has been a continuous expansion of the industry, with manufacturers slowly increasing the size of individual units to meet the demands for steel.

The next major development occurred in 1927 when the Timken Roller Bearing Company in Canton, Ohio, installed a specially designed furnace of 100 gross tons capacity. This unit is elliptical in shape and requires six columns of electrodes. This furnace is the largest ever built and operates continuously, consistent with general business conditions.

There was a temporary lapse in new construction during the depression era following the economic collapse of 1929. The uncertainty of the business outlook forbade the investment of new capital in melting furnaces of very great capacity for some time. This hesitancy prevailed in practically all lines of business,

however, and cannot be construed as pertaining to electric furnace development alone.

In the drive for accurately controlled steels of various analyses demanded by modern metallurgical requirements, the electric arc furnace was found ideal to meet such impositions on the manufacturer. The development of the electric furnace in the United States has made us practically self sufficient in the production of bearing and related steels, considerable tonnage of which was of foreign importation.

While many claims were made as to the superior quality of electric steel following the invention of the process, the resultant product did not always justify them for many reasons. The furnace itself was a new tool in the hands of inexperienced men and coupled with mechanical and electrical deficiencies, it was very difficult for some time to properly place the process in modern industry. It was soon learned that to produce quality metal consistently it would be necessary to improve furnaces, furnace control and melting technique. The net result has been the evolvement of very efficient melting units operated by men of experience and in a position to meet most any problem in quality steel melting demanded by modern industrial needs.

DIRECT ARC MELTING FURNACES

Practically all modern direct arc furnaces are designed for three-phase 60 cycle operation. Power transformers of intricate design are needed to transform the primary voltage to several secondary voltages necessary for efficient control of the furnace. One three-phase transformer with particular attention to the coil structures and proper insulation necessary to withstand the continuous variation in the current and from surge voltages is recommended. The severity of the demands made upon the transformer dictates that it be well designed since it is in effect the heart of the furnace, and failures are costly.

The path of the electric current for each phase is through one electrode, across the arc, through the slag and metal, back through the slag and arc, to another electrode, the circuit being then completed through the external circuit and one phase of the power transformer.

The following electrical equipment is necessary:

1. An oil circuit breaker for the primary supply line.
2. A transformer with suitable primary taps to give proper secondary voltages necessary to efficient operation during melting and refining. In many new installations as many as five taps are provided for, ranging from 265 volts to 133 volts for 50 ton furnaces.
3. A reactor, to serve as a buffer against the heavy current surges formed during the melting period is sometimes used in smaller furnaces.
4. Copper busses and leads to conduct the heavy currents from the transformer to the furnace. These busses must be of ample capacity. A recent development is to water cool the copper leads and encase them in heavy rubber fabric tubing.
5. Automatic and manual equipment, instruments for measuring power input and switch gear necessary to efficient control of electrode positions and power input.
6. D-c. motors for operating the electrode hoisting gear and a furnace tilting motor. A new worm gear assembly has recently been built and installed which is noiseless in operation and can be changed with a minimum of delay if necessary.

There are two types of direct arc furnaces in use, each having some particular merit and application to various melting processes. These are top charge and door charge. The problem that is perplexing many engineers today is which type of furnace to install. It may be said that due to the flexibility in electric furnace con-

FIGURE 2—This modern thirty-five ton furnace, equipped with 10,000 kva. transformer, was designed to give prolonged roof and lining life.

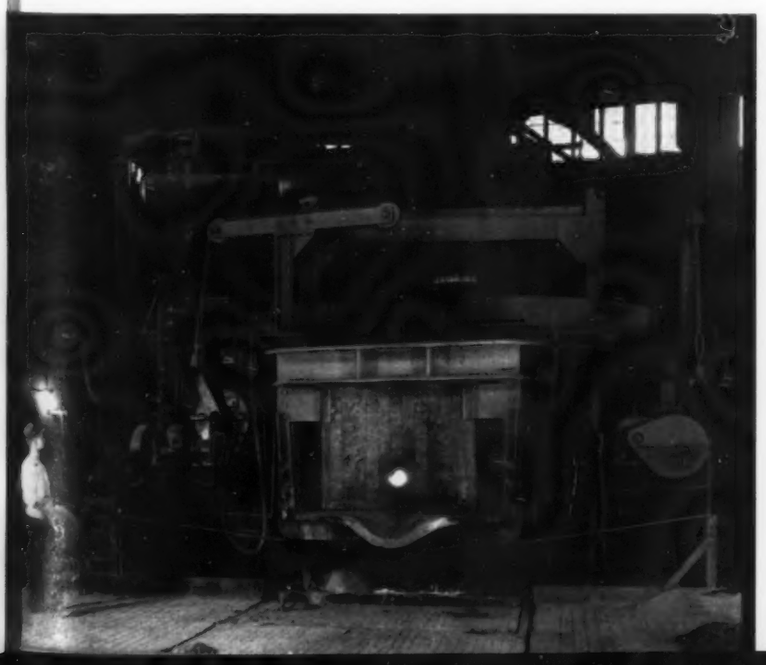


FIGURE 3—This sixty ton furnace is charged through the side door, and is equipped with 12,500 kva. transformer capacity.

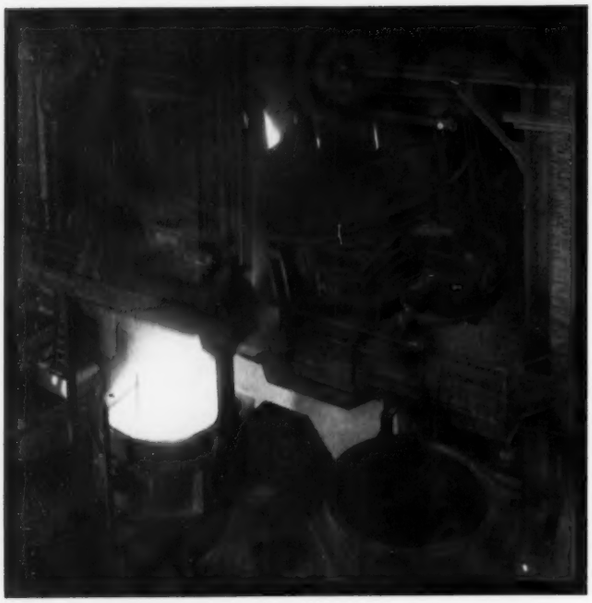


FIGURE 4—This one hundred ton furnace, the largest in the world, uses six electrodes and receives power from two 10,000 kva. transformers.

struction, each must be looked upon as fitting the particular problem of plant operation where installed. Metallurgically speaking, it has not been proven that either type has an advantage over the other in furnaces under 16 ft. in diameter. In larger furnaces, the door charge types have the advantage from an operating standpoint for several reasons to be discussed later.

In plants where smaller installations are desired for ingot melting and in foundries, the top charge furnace is advantageous since hand charging is costly and inefficient. In fact, where charging machines are not available or contemplated, top charge types are a necessity in larger furnaces. It simply means that the furnace be designed to fit the plant layout.

Figure 1 shows one of the earliest Heroult furnaces being charged. This furnace, of 6 tons capacity, was installed in the plant of the Timken Roller Bearing Company in 1916 along with four others. The installation throughout was very elementary and difficult to operate efficiently. Refractory costs were high due to the squat design of the furnace, electrodes were of poor quality and subject to much breakage, regulation of the power input was only semi-automatic and hand charging was necessary. From the experience gained in operating these furnaces, it was found advisable in 1927 to dismantle them and build a new melting department along more modern lines.

Figure 2 shows one of the new door-charge 35 ton furnaces recently installed in the plant of the Timken Roller Bearing Company, replacing a 30 ton furnace, which had been installed in 1927. This furnace was designed to give due regard to atmospheric volume in prolonging roof and lining life during a campaign. This design has resulted in a 30 per cent saving in refractory cost over the previous 30 ton furnace. Data on this furnace is as follows:

Shell diameter ..... 16 ft. 6 in.
Fore plate up ..... 5 ft. 2 in.
Fore plate down ..... 4 ft. 4 in.
Total depth ..... 9 ft. 6 in.
All welded shell.
18 in. silica brick lining, average life 105 heats.
9 in. roofs, fixed, average life 53 heats.
Charging door opening 42 in. high x 48 in. wide.
Roof rings and leads water cooled.
Heavy wall water piping imbedded in furnace wall for structural strength at high temperatures.
Electrode ports in roofs designed for 42 in. electrode centers, forming an equilateral triangle.
18 in. graphite electrodes.
18½ in. inside diameter copper coolers to protect ports.
Horizontal mast arm insulated with ½ in. asbestos tubing inside of mast arm.
Solid wedge type holders.
Electric motor door lifts.
Automatic stops on electrode mast hoists.
Conveniently located valves to control any part of the water system, also a master valve.
Water pressure maintained at 42 lb.
Platform attached to furnace.
Forward tilt 44 degrees, backward tilt 18 degrees.
The furnace, mounted on rockers, taps opposite the charging and slagging door. This permits good tap hole and spout maintenance.
The bottom is composed of rammed material and is insulated.
10,000 kva. transformer.

Figure 3 shows the 60 ton furnace tilted over immediately after tapping. The design is essentially the same as the 35 ton furnace shown in Figure 2. One difference may be noted in that the middle electrode is moved out in front of the other two, since this installation is charged from the side door. This set-up has a particular advantage because there is no arc to play upon the back wall adjacent to the masts. This area is generally the hottest part of the furnace and subject to greatest erosion of the banks and lining, therefore the heat input is more evenly distributed by re-arranging the electrode holders. In this connection it is advisable to reinforce the middle horizontal cross arm to prevent warpage caused by flame impingement from the other two ports. This arm may also be water cooled. It is also possible to service the electrodes freely and safely from a safety platform with this arrangement. Dimensions of this furnace follow:

Shell diameter ..... 19 ft.
Fore plate up ..... 5 ft. 2 in.
Fore plate down ..... 5 ft. 4 in.
Total depth ..... 10 ft. 6 in.
Roof ..... 12 in. (av. 35 heats)
Lining ..... 18 in. (av. 70 heats)
Transformer ..... 12,500 kva.
Five secondary taps .. 133, 150, 200, 230, and 260 volts
Electrode centers ..... 48 in.

The lining and roof life is less on this furnace than on the 35 ton. The power input is extremely high for fast melting with a subsequent greater erosion on the lining. The power input must be carefully controlled and observed at all times for efficient performance, especially

during the melting period or else a burned lining is the result. It is felt that in future installations the shell from the fore plate up should be increased at least 6 in. to give more atmospheric volume which will give a better lining life. It might be said that it is not actually known just how deep a furnace should be for best performance, but by trial and error it is being approximated by actual operation.

The furnace in Figure 4 is of 100 tons capacity and is the largest producing electric furnace in the world. The shell is elliptical in shape and requires 6 columns of 18 in. graphite electrodes, power being supplied by two 10,000 kva. transformers. The assembled roof weighs approximately 30 tons and great care must be exercised in building and handling it. Data on this furnace follows:

Length of shell	29 ft.
Width of shell	20 ft.
Fore plate up	5 ft. 3½ in.
Fore plate down	5 ft. 4 in.
Total depth	10 ft. 7½ in.
Transformer taps	113, 128, 195, and 222 volts
18 in. lining	Av. 86 heats
12 in. roof	Av. 43 heats
Electrode centers	58 in.

Contrary to general opinion when first installed, the control of metal chemistry is remarkable in that the melting hazard is less than 1 per cent.

Figure 5 shows a special cone shaped Heroult furnace with fixed roof. This design is one of the newer developments, and whether it can supplant the vertical wall type for efficiency time alone can tell. As the angle of incidence is equal to the angle of reflection, by flaring back the walls, it is entirely logical to assume that the radiant heat from the arc is diffused to a greater extent and not concentrated in the area surrounding the electrodes. In addition to this, the side walls receding are farther away from the concentrated heat of the arc, therefore greater refractory life is to be expected. It also has a slight advantage of being able to bank the side walls to a greater degree than on the standard cylindrically shaped unit, although the angle of flare is hardly great enough to allow a comparison of this with the famous sloping back wall. The main object of the cone shaped unit was to improve refractory conditions on the roof and lining, and at the same time provide a larger volume for charging, which with the present day scrap has some merit. It is claimed that as high as 275 heats have been obtained with one lining and close to 100 heats per roof while using the carbide type slags in processing. However, in building up high banks it often happens that they become too thick in the region around the slag line and extending to the bottom. If the operators are not very careful, the banks may become so thick that the electrodes will bore into them while melting, causing holes difficult to repair. Also, the jambs necessarily are so wide that it is difficult to properly view the whole bottom for servicing. These blind spots are a disadvantage during the melting process, especially if a boil should develop in these regions. This furnace has an all-welded shell, 15 ft. 8 in. in diameter at the hearth, 18 ft. at the top, and is served by a 10,000 kva. transformer. The furnace has a capacity of 35 gross tons, and uses 18 in. electrodes. The roof ring is water-cooled.

TOP CHARGE FURNACES

The three types of top charge furnaces are the roof-swing aside, gantry crane lift and tilting top. Top charging is almost as old as the furnace business itself with the gantry type being developed in Europe and the tilting top and roof-swing aside in America. The modern top charge as used abroad is principally of the gantry type, and the maximum size is 18 ft. in diameter. The largest in the United States is of the roof-swing aside type and is 16 ft. in diameter.

For the tilting top type, the roof is attached at four points to a yoke which is part of the electrode mast backframe. The roof and electrodes are raised and tilted to allow the charge to be placed.

In the gantry type furnace, the electrode mast and roof raising equipment is built into a gantry frame which travels on rails set in the charging floor (Figure 6). When it is desired to charge the furnace, the electrodes are raised to clear the shell and the roof lifted. The roof and electrodes are then carried by the gantry away from the shell and over the tapping pit, which is not in use during this part of the operation. In both the gantry and roof-swing aside furnaces the roof is lifted horizontally so that flexing of the roof ring is eliminated and the whole operation is carried out quickly by means of electric control.

In charging the roof-swing aside furnace, the operator moves one valve to lift and swing aside the roof, superstructure and electrodes after which the charge is lowered into the furnace in a drop bottom bucket and

FIGURE 5—Certain advantages in furnace maintenance and operation are claimed for this furnace of special cone shaped design.

discharged, the roof then being swung back into place. Care must be taken that the charge be placed in the center of the furnace, otherwise uneven melting would occur. The oil pressure for the lift and swing-aside movement is ordinarily furnished by means of a motor driven pressure pump which draws oil from its associate reservoir tank for operating the heavy double anchored lift and swing-aside-cylinder. This mechanism is properly protected by sequence movement interlocks. The hydraulic pressures available in many plants may be used. Figure 7 shows a small unit and illustrates the principle as used in furnaces of all sizes.

The tilting top furnace is limited to small installations where flexing of the roof brick and electrode columns are at a minimum. This type is not practical in the large units, since the re-distribution of weight flexes the roof brick during the tilt. The radiated heat would be intense during this part of the operation. A number of

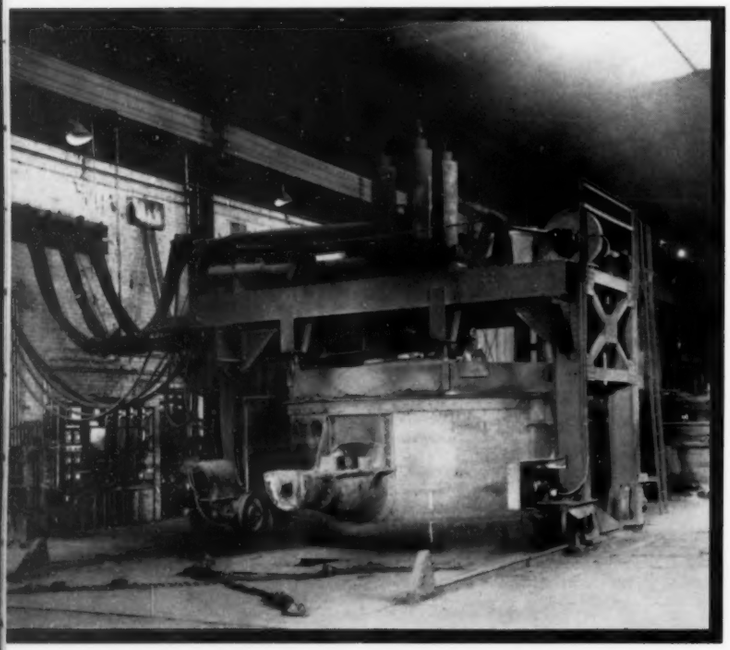


FIGURE 6—Top-charge furnace with electrode mast and roof raising equipment built into gantry frame which travels on floor.

small units are operating quite satisfactorily. However, there are fewer units of this type than the others.

Top charge furnaces are efficient up to 16 ft. in diameter, when all the charge can be placed in the furnace without resorting to re-charging, which is necessary in many alloy shops today due to the light bulky scrap on the market. If re-charging is necessary to complete a charge, care must be taken that the scrap be kept dry or else the dropping of additional scrap in a pre-molten bath would result in an explosion if the scrap were damp. When charging machines are used it is possible to carefully place the scrap in the furnace, and if damp, dry it inside the hot furnace before dumping it into the molten bath. Since in large production shops the scrap is often loaded into the charging receptacles direct from cars, it can be readily seen that water and ice in the scrap creates a hazard to contend with. In shops where the scrap may be selected as desired, especially when the electric furnace is operated in conjunction with the open hearth, top charge furnaces are desirable. In foundries and small alloy shops the top charge furnace is more practical and economical.

Door charge furnaces are the more practical for large units, especially when all types of alloy steels are melted. A machine is necessary to handle heavy alloy additions and slag making materials or else much time is lost doing this work by hand. In fact, there are many things in working around a furnace in which a charging machine is a great aid aside from charging. In connection with door charge furnaces much thought has been recently given to the enlargement of the door openings and increasing the volume of the charging boxes to better handle light bulky scrap and expedite charging generally. There seems to be no sound reason that it be necessary to adhere to the so-called standard charging box. This program would, of course, speed up the scrap loading and charging phase of operations.

It may be a little early yet to properly evaluate the worth of the cone type shell in comparison with the vertical shell. Some operating difficulties have been encountered as might be expected with any new venture, but apparently some of these difficulties have been eliminated. It might be said in this connection that thought is being given to the flaring of the shell from the furnace bottom rather than from the fore plate. If door openings are increased in this design, it will probably be possible to better view the furnace bottom. However, the newly designed vertical shell units are very efficient and difficult to improve upon.

The general trend is toward higher power input in all furnaces. Since a transformer should not be operated at its maximum capacity for best service, it is wise to install one large enough so that over-loading may not occur. There is no yardstick to measure the amount of power to be used in furnaces generally. The power input depends mainly on the type of scrap to be melted, whether heavy or light, and the depth of the bath. A higher power input can be handled more easily when melting light scrap than heavy. Types of metal to be melted will also dictate to a great extent the permissible speed of melting for best results. The problem therefore boils down to the point that individual study must be given to a certain set of conditions which one must cope with in producing the desired product.

The largest graphite electrode being produced at the present time is 20 in. in diameter and designed for capacities of from 12,000 to 15,000 kw.

The question has often been raised as to how large a circular furnace could be before it became too unwieldy and difficult to operate. It must be borne in mind that after tapping a heat of steel out of any furnace there is no means provided to keep the furnace hot. Should holes develop in the hearth or banks, they must be rabbled manually before the metal solidifies. The larger the hearth area the more difficult this becomes. This differs from open hearth maintenance in that the tap hole is on a level with the bottom and heat may be applied as long as needed to complete repairs. It is felt that for this reason and others connected with metal and

slag control that a cylindrical furnace 20 ft. in diameter and 11 ft. 6 in. deep with 6 ft. from the door sill to the top of the furnace shell, giving due regard to the atmospheric volume, would be about the ultimate. With proper brick work and bottom design this furnace would produce approximately 160,000 lb. per heat.

ELECTRIC FURNACES IN THE FERRO-ALLOY INDUSTRY

Just a brief word about the electric furnace in the ferro-alloy industry, particularly in its use in the production of ferro-silicon of a silicon content of 40 per cent and over.

The trend is, of course, like steel furnaces, to higher power input per unit and production units of 10,000 kva. installed capacity are now in operation. However, 6000 to 7000 kva. is possibly indicative of the majority

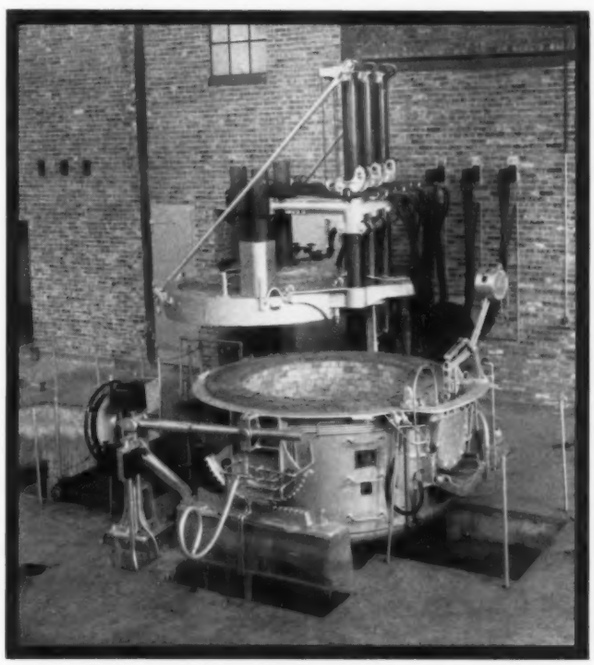


FIGURE 7—In this type of top-charge furnace, the roof and electrodes are lifted and swung aside on a jib arrangement.

of the furnaces operating at this time. Most of the furnaces operate on voltage ranges of 75 to 145, and usually are 3-phase 25 cycle, although some operate on 60 cycle. The 25 cycle units are capable of 90-plus in power factor, while the 60 cycle units range a shade lower—say, 85 to 90.

The furnace itself is a steel shell, electrically welded, of round, oval or rectangular shape. It is lined, bottom and sides, with carbon blocks. Some of the furnaces have roofs, but the majority do not, and are what is termed "open top furnaces." The size of the furnace is controlled by the power input, the size of electrodes, and so forth. In some of the large round furnaces, the shell is 35 ft. in diameter. The depth of the furnace, after lining, varies from 4 to 6 ft.

The electrodes are carbon, in round, square or rectangle form. The square and rectangle shapes are used in one length, usually about 180 in. long and ranging in size to as large as 24 x 30 in. in cross section. The rounds are continuous, through the joining, by nipple, and range in size from 20 to 40 in. in diameter. The round, naturally, gives the most economical use in pounds per ton of electrode consumed, by the simple elimination of the butt loss encountered in using the square or rectangle shapes. The electrodes enter the furnace vertically, and their position is either in line or spaced in the triangle—the latter is the accepted installation today. The furnaces operate as what is termed a "submerged arc type," meaning that the tip of the lower end of the electrodes is constantly surrounded by the charge and raw materials are constantly fed to replace the reduced material that is being tapped from the furnace.

The furnaces are continuously charged with the "mix," by hand mostly, but a few are mechanically

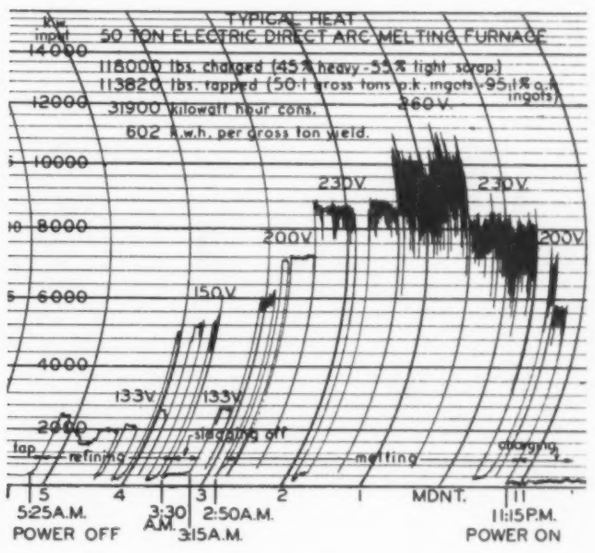


FIGURE 8—Chart showing power input and voltage during a heat of alloy steel in a modern fifty ton furnace.

charged. They are tapped similar to a blast furnace, at stated intervals, and except for delays, either mechanical or electrical, the furnaces, when needed, operate 24 hours per day, 7 days a week, and so forth. The finished production normally has been cast in what is termed "sand beds," but the trend is toward casting in metal containers, eliminating possible inclusions of trapped sand, and so forth.

POWER AND FURNACE EFFICIENCY

The chart in Figure 8 shows the power input and voltages applied at various stages throughout melting and refining a heat of alloy steel in a modern 50 ton

electric furnace. The charge consisted of 45 per cent heavy mill scrap and 55 per cent fairly light low phosphorous scrap. At the start of the melting period the intermediate voltages were applied to permit the electrodes to bore through the scrap mass more readily to the bottom of the hearth. The heavy scrap was charged directly on the bottom of the furnace followed by the light. If too high voltages are used at the beginning of the melting period, bridging of the molten metal over the heavy scrap may occur with a resultant cold melt and skulled bottom. When this occurs it is very difficult to properly heat the bath and a burned furnace is the usual result, due to the reflected arc and radiation from a superheated slag and bath. From a mechanical as well as a metallurgical standpoint it is always best to control the power input in such a manner that when the melting cycle is completed, the bath temperature is uniform throughout and the bottom is clear. This is very important for quality control in alloy steel melting. The total time from power on to power off at tap was 6 hr. and 5 min. The heat was of alloy grade and approximately 2 hr. were consumed refining under a carbide slag after removing the melt down slag. It should be noted that the physical characteristics of a charge will dictate to a great extent the variations in power input necessary to meet changing conditions.

Power consumption, per cent of good ingot yield and tap to tap time have been compiled on heats of comparative types of steels, all alloy, from various sizes of electric furnaces over a six month period of time, and the data is shown in Figure 9. The same size ingots were cast from the small furnace as from the large. The ingot yield from the ten ton furnace is low because the scrap losses in casting are proportionately higher due to butt loss. For greater efficiency small ingots should be cast, thus cutting down this loss. However, when large sections are desired, this is not always possible.

The total sensible heat above 32 degrees F. for steel at tapping temperature of 2900 degrees F. is taken at 617 Btu. per pound.

$617 \times 2000 = 1{,}234{,}000$ Btu. of sensible heat per net ton at 2900 degrees F.

1 Btu. = .0002931 kwh.

$1{,}234{,}000 \times .0002931 = 361.7$ kwh. per net ton

Power equivalent of sensible heat in 1 net ton at 2900 degrees ÷ power consumption per net ton of good ingots = power efficiency.

10 ton furnace, $\frac{361.7}{723.3} = 50$ per cent power efficiency

30 ton furnace, $\frac{361.7}{601.0} = 60.2$ per cent power efficiency

35 ton furnace, $\frac{361.7}{585.8} = 61.7$ per cent power efficiency

60 ton furnace, $\frac{361.7}{556.3} = 65.0$ per cent power efficiency

100 ton furnace, $\frac{361.7}{540.3} = 66.9$ per cent power efficiency

The above formula for finding the power efficiency may be applied to any furnace, but the results will vary in accordance with melting procedure as used in different plants. However, from the above chart the larger melting units are the most economical to operate under any melting practice.

Furnace size in net tons	Power consumed per net tons of good ingots, kwh.	Per cent yield, good ingots	Time of heat, tap to tap, hr.	Net tons per hour
10	723.3	90.2	5.50	1.82
30	601.0	94.8	6.25	4.80
35	585.8	95.0	6.50	5.38
60	556.3	95.8	8.08	7.43
100	540.3	96.3	9.25	10.81

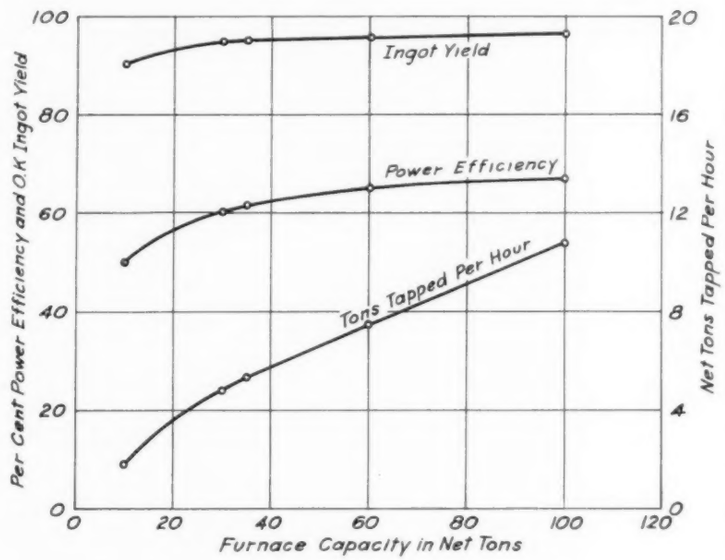


FIGURE 9—Curves showing six month average of yield, power efficiency and production rate for alloy steel in furnaces of various size.

The above figures have been calculated from a sustained operating period of six months and include relining and all other operating delays.

FURNACE PRACTICE

The type of lining and bottom to be employed in melting depends on whether the acid or basic process is to be used. If the main function of the unit is for melting, the acid process is particularly adapted and lends itself favorably to foundry practice. The slag formed during melting is very siliceous in nature and since the lining and hearth are of silica there is little or no chemical reaction to flux the walls and roof,

thereby contributing to long furnace life. Given good operation an acid lined furnace will operate 600 to 800 heats per campaign in the simple melting process. Some alloy steel is being made in the acid furnace. To do this it is necessary to select scrap very low in phosphorous and sulphur since the chemistry to the process does not permit the phosphorous to be oxidized or sulphur to be eliminated to any great degree. In the manufacture of alloy steels where refinement of the metal is required, and phosphorous and sulphur must be at a minimum, the basic process is used. Since all large furnaces are employed mainly in the production of alloy steels, they are of basic bottom construction and some description of basic electric practice will follow.

The first requisite to produce good steel is a good bottom. Rammed bottoms of suitable material have proved to be as efficient as burned in bottoms. In ramming in a bottom, it is possible to obtain a hearth which is high in MgO (60–70 per cent) without the silica infiltration from over heated walls and roof, which often occurs during the burning in process. In burning in a bottom it is necessary to add open hearth slag to the magnesite in order to lower the fusion point to somewhere around 2950 to 3000 degrees. This temperature is quite close to the fusion point of the silica brick in the lining and roof, and is hazardous. Additions of lime, fine ore, tar, scale and sand have also been used to lower the fusion point of the magnesite. The net result in a burned in bottom is one in which the MgO content is about 50 per cent. The mechanics of putting a bottom in a large furnace are difficult when the burning in process is used. A rammed bottom is more refractory, easier to build, eliminates the hazards of burning and costs no more. In ramming a bottom care must be taken that the sub-hearth be properly constructed. It is best to shape the hearth with the brick work before ramming. In electric furnace bottom construction the rammed material need not be over 6 in. thick in the 10 ton furnace to 10 in. thick in the 60 ton and 100 ton furnaces. When the bottom has been rammed in, it should be brought up slowly to around 2900 degrees before preparing to charge. This phase takes about 24 hr. for completion in the larger furnaces.

In constructing the sub-hearth sufficient fire clay brick should be used to properly insulate the bottom. A first course of insulating brick may be used but is not necessary. In any event the bottom should be well insulated, because the magnesite is a good conductor of heat, and otherwise would tend to chill the metal adjacent to the hearth. This would not be conducive to good metal control.

To the problem of how long an electric furnace bottom should be used before rebuilding, it might be said that it depends entirely on the condition of the bottom in question.

If the hearth is found unfit for good melting practice, it should be renewed, whether it be in use six weeks or six years. Many of the ills of steel making can be traced to poor hearth condition and it seems illogical to attampt to melt high quality steels in unsound melting vessels. After a number of campaigns the best of bottoms will absorb metal, slag, silica and alloys. When a bottom has reached the point where good maintenance is difficult and is causing trouble in steel production, it should be renewed. Given good operating conditions a well set-up bottom is generally good for about two years.

While the bottoms in furnaces used in basic melting are of basic materials the sidewalls and roofs are generally of silica construction. The high cost of magnesite linings and the spalling tendencies during the thermal changes in furnace practice tend to favor silica brick construction. Although some added furnace life may be expected with magnesite brick linings, the cost of construction is too high to replace silica linings from an economical standpoint. In small furnaces where exceedingly high temperatures are desirable, it is wise and practical to use magnesite linings. While many types of brick have been experimented with, it can be said that a good silica brick, properly laid, is the best, especially in the larger furnaces. To greatly increase furnace life it has been found advisable to imbed heavy wall water piping in the furnace wall during construction to give structural strength at high temperature. This pipe is bent in the form of a single or double hairpin and is placed at least 18 in. above the slag line. In the hottest areas adjacent to the electrode this has been found to be invaluable. (Figure 10)

Silica brick roofs are the most practical and economical in large furnace construction. They are lighter and have greater structural strength at high temperature than the clay brick roofs. A roof about to fail is more easily detected when built of silica brick than of clay. This is very important since an unexpected roof failure can cause much damage should one drop when the bath is at a high temperature. Cooling rings could easily be submerged in the molten metal with a resulting steam explosion, should this occur. Permissible expansion in setting up walls and roofs need not be noted here since furnace operators and ceramic engineers understand the physical characteristics of the various kinds of brick.

Insulating electric furnace roofs is not practical. In fact, experiments conducted in roof insulation have shown a decided drop in roof life, due to the building up of a reservoir of heat in the roof itself, and allowing the inside face of the roof to reach a high temperature quickly and melt readily. It has been found best to keep the top of the roof clear of all foreign material and exposed to the air so that heat may be conducted through and away from the roof brick readily.

SLAG AND METAL CONTROL

The most important thing in quality steel production is to eliminate the burden on the steel melter as far as possible. This can be accomplished by standardization of practice from the purchasing of the raw materials to the delivery of the finished ingots for further processing. When this is done melting hazards are to a great extent held to a minimum. Despite the fact that volumes have been written on the chemistry of steel making and the knowledge of steel melting is increasing, it must be recognized that the quality of the steel as produced is in the hands of the man who makes it—the steel melter. Therefore, in eliminating all variables possible, a great step has been taken to insure steel of consistent quality.

In producing basic electric alloy steel in the arc furnace two distinct types of slags are generally used

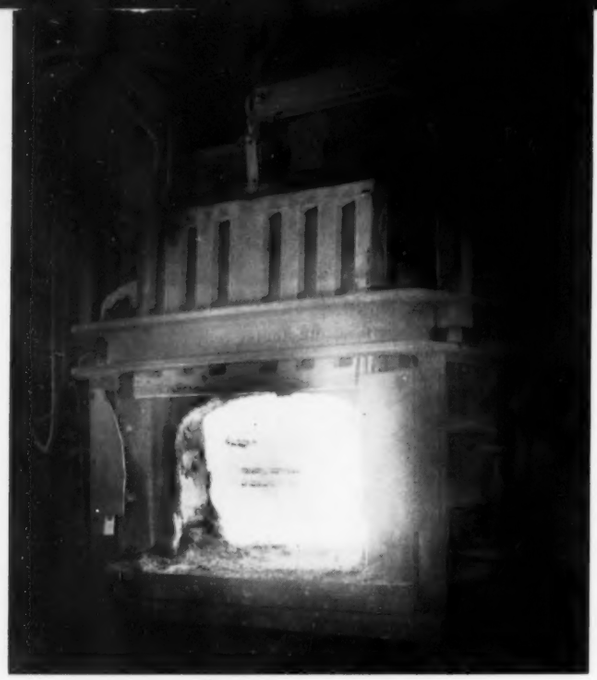


FIGURE 10—View showing method of construction in order to obtain increased furnace life.

on each heat. The first slag is formed during the melt down period by the addition of lime or limestone to the charge, which combines with the oxides during melting, and any bottom erosion which may take place. Oxidation of the bath may be controlled to the desired degree under this slag blanket. In most types of engineering steels it has been found advisable to keep this slag very basic and fairly high in FeO, about 10 per cent. The oxidation of phosphorous and silicon takes place at this stage, also any other element of an oxidizable nature which may exist in the charge.

Close attention must be given to the condition of the metal and slag before proceeding further. It must be made certain that the metal is all melted clear of the bottom so that the bath temperature may be equalized throughout. After the phosphorous is oxidized, the metal should be brought to a fairly high temperature, because all other phases of melting will proceed more easily if this is done; solubility of alloy additions, reactions between metal and slag and flotation of the products of de-oxidation will take place more quickly and thoroughly in the higher temperature ranges. Freedom from segregation because of better diffusion is also attained. Should the metal be reacting over the entire surface at the melt-down, it is a fair indication that the metal is hot and the bottom free of scrap. Too much emphasis cannot be placed on the proper conditioning of the metal before the slag-off period. It is at this time that the tapping temperature is controlled and hydrogen and nitrogen removed during the boil. Should the heat be slagged off cold, it would be difficult and often impossible to get the metal hot enough to insure good clean steel for critical applications, such as aircraft, bearing or automotive use.

Having met the above conditions, the bath is ready for de-oxidation, assuming of course, that the chemical composition is correct. The amazing thing about de-oxidation practices is that so many different methods are in use, each designed to impart some definite characteristic to the finished product. Much steel is being tapped without removing the melt down slag, the de-oxidation of which is carried out mainly by ladle additions. Wire, light structural steel and screw stock is generally produced by this method. Practically all of the alloy grades are produced by removing the melt-down slag and finishing the heat with some variation of the carbide or silicon type slag. The Sheffield firm of Thomas Firth and John Brown use a slag of pure calcium carbide to obtain exceptionally clean steel and low sulphur. In American practice the carbide slag is formed in the furnace with proper additions of lime, fluor spar and crushed coke to which silica sand is sometimes added to confer fluidity. The CaC_2 content of the slag can be easily controlled to conform to the desired content. The desired amount of CaC_2 in the slag is at present an argued point. However, most of the alloy ingots in the carbon range about .15 per cent are made under a very reducing slag, the FeO in the slag and metal being quite low. In Figure 11 the possible control of FeO in steel and slag by carbide slag manipulations is shown. The CaC_2 content of the slag was maintained at about 2.50 per cent throughout the reducing period; .07 per cent of silicon was added to the bare bath after slagging off.

In most types of steel of .10 carbon or under the medium for slag de-oxidation is fine silicon or calcium silicon. This is necessary because the use of any carbonaceous product would result in a carbon pick-up and therefore is objectionable. Since most of the low carbon steels are of the stainless types and expensive to produce, it is very necessary that the carbon be kept under control to eliminate the possibility of off chemistry steel. Care must be taken that all slag making materials be dry or else hydrogen may be absorbed in the molten bath, especially when the slag and metal is in a highly de-oxidized state. One method to forestall such absorption is to work the heat with about 1 to 2 per cent FeO in the slag. It is generally recognized that slag and steel reduction can be carried too far with resultant gassy steel. Another method which is growing in use is to substitute cement clinker for the slag base instead of lime. The clinker will not absorb moisture and can safely be stored for a long period of time. It also contains enough FeO that it is difficult for a slag to reach a high state of de-oxidation, even with the use of fine silicon. It will also be found that silicon absorption into the metal is less with the use of cement clinker than with lime and therefore this element is under better control.

Wihle calcium carbide and silicon type slags are strong reducing agents, it still remains for silicon and the judicious use of aluminum in the metal to obtain complete de-oxidation and produce sound steel. In this phase of melting the electric furnace excels, in that the metal may be completely made in the furnace without resorting to ladle additions, which is objectionable in many cases. Because the slags in the ladle are low in FeO the metal will maintain consistent chemical and physical characteristics throughout the pour. This is especially important to large furnace operation since

the metal may be in the ladle from 40 minutes to one hour.

It would be impossible within the scope of this paper to properly analyze the reasons for the various practices in use. From the production of tool steel and specialties to simple carbon products, the melting procedure must be metallurgically designed to meet the problem of producing each grade.

Progress in producing better steel has not been monopolized by the electric furnace alone, but the process has provided the means to develop many types to a higher degree than by any other method. This is also true in non-ferrous metallurgy.

The versatility of the electric furnace as a melting medium is also expressed in the ability to remelt scrap containing a high amount of oxidizable alloys with a minimum of loss. This can be done because oxidization of the elements can be controlled. If necessary, the bath may be oxidized to a certain extent to eliminate carbon and then reverse the process with the use of fine silicon in the slag to return the metallic oxides back into the bath by reduction.

The reduction of ores in the slag to replace ferro-alloy additions in alloy steel melting is being widely practiced. Chief among these are the ores of chromium and tungsten.

It may also be noted that the electric furnace plays an important part in the conservation of manganese, chromium and tungsten since by the chemistry of the process melting losses of these strategic and essential elements are held to a minimum and are negligible.

In melting steels containing selenium, titanium, columbium, aluminum or any of the highly oxidizable elements special slag treatment must be designed to keep the desired analysis of the final product under control. Steels with an appreciable amount of the above elements are difficult to produce and great care and skill are necessary for successful manufacture.

In producing quality steel it is necessary to control the hot metal, not only in the furnace but in the pouring operations as well. A great amount of attention is paid to the cleanliness of spout, ladles, and molds. Special attention is directed to the setting of nozzles and packing material in the ladle well. This material should be of a composition that will not be washed out during the pour. A new mold plug which is gaining favor is made of graphite. Contrary to expectation, this plug washes out very little during the pour, therefore, there can be no pick up of fire clay materials or carbon in the ingot from this source. The reason for the above precautions is to eliminate as far as possible absorption of non-metallics in the metal. Deep study has been given to mold design, proper mold temperature and pouring rates for the various types of steel. In fact, the necessity for the best of pit and pouring practice in casting expensive steels has resulted in a better product when applied to the simpler alloy types.

According to figures compiled by the American Iron and Steel Institute, there was a total of 3,211,955 net tons of alloy steel ingots and castings made in the United States in 1939.* Of this, 749,384 net tons was the product of the electric furnace, or 23.3 per cent of the total. This was the record year in electric alloy steel production. In 1929, 4,432,072 net tons of alloy steel and castings was the total product of which 12.9 per cent or 571,234 net tons was the product of the

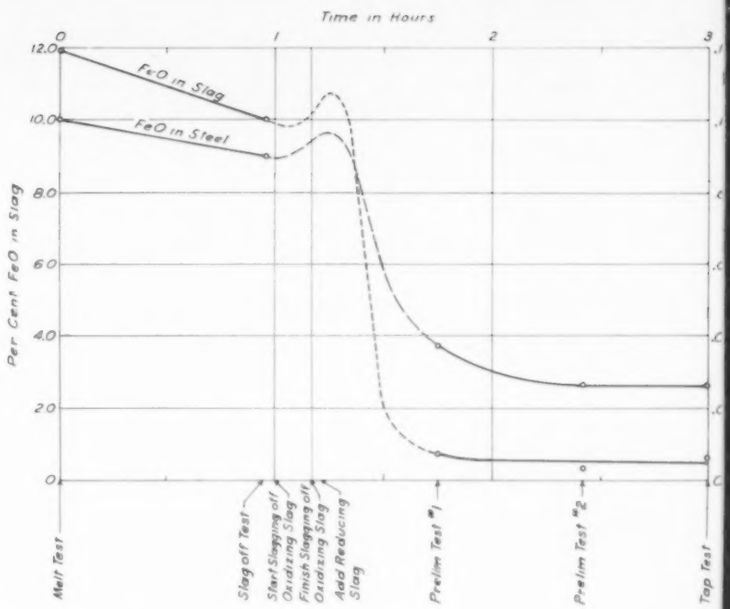


FIGURE 11—Curves showing the possible control of FeO in steel and slag by carbide slag manipulation.

electric furnace. The electric percentage of the total output has been constantly increasing during the past ten years. The total electric furnace product in 1939 was 1,029,067 net tons and the total capacity estimated at 1,592,080 net tons. Due to the expansion taking place in the industry it is thought that this figure will be increased to about 1,850,000 net tons. Pennsylvania led in electric furnace capacity in 1939, but completion of a number of new units in Ohio plants during 1940 will place this state considerably in the lead with about 530,000 net tons annual capacity.

In April, 1940, there were 430 electric furnaces of 1 ton capacity or over engaged in melting iron and steel; 120 of these were of 6 tons or more. During 1940, many new furnaces have been put in operation, and still further expansion is in progress.

The development of stainless and heat-resisting steels and non-ferrous products have played an important part in forcing the industry to expand. However, since the electric furnace has demonstrated its ability to properly control chemistry, cleanliness, inherent grain size, physical characteristics and to meet magnaflux requirements consistently, in the simpler alloy grades, added impetus has been given to supply the demand for steel.

The argument that quality steel could not be made in furnaces of over 10 tons capacity must be denied. In fact, within the last several years metallurgists, realizing that less testing is necessary and that the larger heats are more uniform and consistent, have specified the product to be made in the larger furnaces. This state-

*The figures for 1939 include only that portion of the steel for castings which was produced in foundries operated by companies producing steel ingots.

ment may be proven by the number of large furnaces being installed to supply the trade. Of course, the small furnace still has its place in the foundry, in the melting of tool steels, specialties and small orders. The answer to the problem of proper furnace size probably may be found on the melting floor. Any melter having had experience with both large and small furnaces will agree that the larger units are more easily controlled, because the chemical reactions take place more slowly and can be readily followed in conjunction with the chemical laboratory and carbon determining instruments.

One problem to be solved yet is the accurate measurement of bath temperature in the furnace. This does not apply to the electric furnace alone, but to all melting processes. Optical pyrometers and various other instruments have been devised to measure temperature, but none as yet are absolutely reliable. In conjunction with the experienced eye of the melter, instruments serve as a check on his judgment in determining proper tapping temperatures, and are valuable from this standpoint.

The modern electric arc furnace has developed into a highly mechanized installation. The equipment throughout has been designed for ease of control which is so necessary to the efficient operation of the large furnaces. Electrodes are of very good quality and failures are few.

It would be difficult to name one phase of improvement which contributed more than any other to the advancement of the electric furnace process. The development work of the mechanical, electrical, ceramic and metallurgical engineer was dependent in large measure on the success of each one in his particular field.

The increase in furnace capacity will no doubt bring added problems to the producer. The demand for high grade low phosphorous scrap will increase, with a probable price premium. Those furnaces which operate in conjunction with open hearths will be the least affected since much of the resultant scrap may be diverted to the electric furnace. If duplexing may become necessary, the combination shop would have an added advantage. It is rather difficult at the present time to forecast just what the situation may be regarding metal mixes in the future. However, thought should be directed to the possible state of the scrap market and plans formed to meet any change. The electric arc furnace in the hands of experienced operators has proven to be exceptionally versatile and in a position to ably meet changes found necessary.

DISCUSSION

PRESENTED BY

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G. E. STOLTZ, *Manager*, Metal Working Section, Industrial Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

L. V. BLACK: Assuming that all electrical equipment used in conjunction with arc furnaces is purchased with adequately designed features to withstand the severe duty imposed upon them for this type of service, my belief is that the electrode hoisting mechanism, that is motors, hoisting medium, control boards, and regulator panels, play the most important part in the successful operation of the furnace. Prevention of electrode dipping, rapid raising of the electrodes from the bath, and high speed incremental steps of electrode movements are a prime requisite for producing certain grades of steel.

As stated by the author, a reactor is used as a buffer against heavy current surges on some furnaces. This is particularly true for furnaces operating on a 25 cycle system. On 60 cycle power supply systems a reactor is not so essential unless the surges during melt down periods upset the stability of the power supply to the extent that other pieces of equipment served by the same supply are affected. Modern design arc furnaces have sufficient reactance built into the furnace and transformer circuits so that an external reactor becomes unnecessary.

The spacing of electrode centers with respect to the size and shape of an arc furnace is an important problem in the design of the furnace. Improper spacing will either produce inefficient melting, or excess burning out of the refractory side walls, and will affect to a large extent the power input per ton of steel.

The furnaces in operation at the Bethlehem plant of the Bethlehem Steel Company are as follows:

One 6 ton furnace having a 12 ft. diameter hearth, using 12 in. diameter electrodes. The control and switchgear is so wired that the 4000 kva., 3 phase, 25 cycle, 6600 volt furnace transformer will supply 41.5, 50.5, 103, and 140 volts to the arc of the furnace.

One 25 ton furnace having a 15 ft. diameter hearth, using 18 in. diameter electrodes; has 14 steps of arc voltages between 48.5 volts and 154 volts. Power is supplied by a 6250 kva., 3 phase, 25 cycle, 6600 volt transformer, equipped with the necessary oil coolers to enable the furnace to draw 13,000 kva. during melt down periods.

Two 50 ton furnaces are now being installed, the first of which will be in operation before the end of 1940. These furnaces have a 20 ft. diameter hearth and 20 in. diameter electrodes. Various steps of arc voltages are available between 95 and 162.5 volts on delta and between 55 and 94 volts on the star connection.

Electrode holders are a very important part of the furnace. Their design should be carefully considered and designed—whether of the water cooled or dry type—so that slipping of the electrodes can be accomplished readily and easily, and at the same time have sufficient strength and rigidity to hold the electrode firm during normal operation. A poorly designed holder can cause lengthy furnace operating delays and very high maintenance costs.

The flexible cable leads between the furnace holders and the transformer, together with the cable terminals, should be given careful consideration, both from the operating and the maintenance viewpoints. Design of electrode holders, size and shape of flexible cable terminals, spacing of electrodes, copper conductors on the electrode arms, in fact all component parts of the

electrical circuit from the transformers to the furnace charge, are important factors in the permanent reactance built in the arc furnace circuit. The trend seems to be that of designing sufficient permanent reactance in the furnace and transformer circuits to sufficiently cushion the effects of furnace operating surges on the supply high tension system. In my opinion this circuit should be designed with only sufficient reactance to maintain good operating stability for the average heat, and an external reactor, with several per cent taps, should be supplied for use during melt-down periods and abnormal heats. With this arrangement the operator has a more flexible control of the reactance at his command for various operating conditions.

A very important factor in the economical operation of arc furnaces is the charge. Careful selection of the material charged, and careful placing of the charge in the furnace to prevent voids will go far toward reducing the melt-down period and, thereby, decrease the kwh. input per ton of steel melted. The quality, physical nature, and denseness of the charge, has a direct bearing on its ability to absorb heat from the arc. If not properly charged, much of the arc heat will be radiated to the roof and side walls. In other words there is a certain point, depending upon the nature of the charge, above which the charge does not have the ability to absorb heat from the arc. This point will also vary in value from the melt-down period to the refining period. This point of maximum power input to the charge is called the "optimum point" and has been discussed in detail on several occasions by N. R. Stansel.

After all, we know we must begin with theory and end with economical practice. The ultimate point is a good balance between theoretical foundations and economical operating practices.

G. E. STOLTZ: Circuit breakers controlling the high tension side of a steel melting and refining arc furnace transformer, are required to meet difficult service conditions. These are:

1. Frequent voltage surges of varying magnitude inherent in the operation of an arc furnace. These surges are initiated in the secondary circuit, are propagated through the transformer, and are impressed on all the high tension equipment, including the circuit breaker.
2. Frequent opening and closing of the circuit breaker in order to change the operating taps on the transformer.
3. An indefinite number of automatic operations due to short circuits caused by contacts between the electrode and the charge, particularly during the melt down period. Although many of these short circuits are cleared before the induction relays operate by means of the electrode regulator, which quickly raises the electrode away from the charge; some of them such as those which occur when the charge caves in will trip the breaker.

The total number of operations due to either normal or abnormal conditions as noted above, will vary from 30 to 40 operations per day to as many as 120 in certain methods of operating the furnaces.

For many years oil circuit breakers have been used in this service, but the increase in size of the furnaces and the higher service voltages used in recent applications, have emphasized the difficulties when oil circuit breakers are used.

In the first place every time the breaker is opened, arcing takes place with consequent contamination of the oil. Even if the general practice of running the electrodes up before opening the breaker is followed, so that the breaker ruptures only magnetizing current of the transformer, we will still have some arcing and in addition the overload relaying may be such that secondary short circuits may be cleared automatically by the breaker.

In furnace service, however, considerable time is sometimes allowed to elapse before the breaker is inspected or the oil checked. In some cases this interval is far too long. The gradual deterioration of the oil due to carbonization, increases the leakage over creepage surfaces and thus decreases the margin of safety. This occurs also on a circuit which is subject to many voltage surges.

Secondly, the breaker must stand up mechanically to frequent operations. Oil circuit breakers of standard design may not be adapted to such service.

The breaker if arranged for automatic overload protection must clear the secondary short circuits. Sometimes the breaker has the additional duty of clearing primary short circuits. However, on furnaces of large size, supplied from heavy capacity systems, it may be preferable to install an oil circuit breaker of large interrupting capacity to take care of the rupturing capacity of the system and use a smaller interrupting capacity breaker as the furnace breaker. It can be connected so that it opens only the secondary short circuits or be made non-automatic.

When the air circuit breaker was brought out for high voltages, the possibility of using it to avoid the troubles due to oil carbonization were recognized, but it was also necessary to develop the breaker for the mechanical duty required by frequent operation. Since this requirement of frequent operation was also found necessary in other steel mill applications, this development was completed and its use for furnace application is strongly recommended and frequently adopted.

Steel mill practice has also suggested another standard for arc furnace circuit breakers, and that is the use of equipment insulated for the next higher voltage class above the service voltage. The conducting nature of the dust in steel mills, and the frequent voltage surges in the operation of arc furnaces are strong arguments for this practice.

Another recommendation contributing to the safety of the equipment, is the use of surge protective equipment to reduce the magnitude of surge voltages.

A series of tests made on an installation where surges were prevalent, provides that a definite reduction in the magnitude of surge voltages results from the use of high voltage capacitors connected between the transformer and the oil circuit breaker.

The following summarizes our recommendations for arc furnace installations:

1. Air breakers are preferred to oil circuit breakers.
2. Breakers insulated for next higher voltage class above the actual service voltage are recommended.
3. Surge protective equipment reduces the magnitude of surges and is good insurance.

SOAKING PIT CONTROL

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Presented before A. I. S. E. ANNUAL CONVENTION, Chicago, Illinois, September 24-27, 1940

▲ ENGINEERING development progresses in cycles. In the case of the automobile industry, for example, engineering emphasis a number of years ago was placed on four-wheel brakes, similarly, on silent transmissions, floating power, streamlining, etc. Upon completion of each of these engineering developments, the ideas were accepted by the entire industry and the engineers moved on to other problems. In much the same way, the steel industry found its engineers a few years ago occupied with the continuous rolling process. This development emphasized the importance of proper ingot heating in the soaking pit and soon steel mill engineers found themselves giving considerable study to pit operation and design. As a result of this study, several important conclusions are now apparent. As compared with pit practice prior to say five years ago, present-day pit designs produce more and better heated ingots at lower cost. Surface imperfections in slabs and blooms, attributable to improper ingot heating, can be practically eliminated because of the more precise control of furnace temperature and atmosphere available with the new pits. Output per unit of floor space is increased by the more efficient application of heat to the ingot and by the reduction in lost heating time caused by excessive bottom making and refractory maintenance. Cost per ton of ingots is dropped due to the lowered fuel consumption and the decreased labor cost per ton of ingots heated. All in all, everyone will agree that the soaking pit research of the past five years has been productive of highly desirable results.

Many new soaking pits of latest design have been paying their owners remarkable dividends. These newer pits have been built in several different shapes—round, square, and rectangular. In one type, fuel enters the bottom of the pit and flue gases are exhausted at the sides. In another, fuel enters at the sides and flue gases exhaust from the bottom. In another, fuel enters and flue gases leave the pit from the same side, while in still another, the exit and inlet ports reverse at intervals. Fuels used include natural gas, coke oven gas, blast furnace gas, and mixtures of blast furnace gas, with one of the other two. In one case, a mixture of all three is

FIGURE 1—General view of part of installation of sixteen modern pits totaling a heating capacity of 2,000,000 tons per year.

used. In still others, oil, and producer gas firing are used. While different in construction and method of operation, all of these pits have one thing in common—they all include automatic controls as an integral part of the installation. These controls permit study of pit procedure to determine best operating conditions. By maintaining these best operating conditions continuously, the automatic control has helped achieve the success the newer pits enjoy over the old.

The functions of the automatic control apparatus follow in principle the operating methods used by the heater when operating the pit under manual control, with the exception that the judgment of pit temperature, atmosphere, and pit pressure instead of being judged by the variable yardstick of the heater's guess, is now based on direct measurement of the quantities involved. Operating conditions, therefore, are more easily determinable and can more easily be reproduced.

The heater operating a soaking pit is continuously interested in three factors other than the physical handling of the steel ingot. These are rate of heat input, fuel-air ratio, and rate of flue gas removal or furnace pressure. In this respect, his problem is quite like those encountered in the operation of other types of metallurgical heating furnaces. The range over which he must operate his soaking pit, however, is much greater. For example, the pit may be charged with ingots taken from storage and cold throughout, or it may receive ingots immediately after stripping which, while having a solid shell, are still molten within. In either case, he must produce a correctly heated ingot of proper rolling temperature, uniform throughout its entire mass, free from washing, and having the right kind and thickness of surface scale, which will be removed completely after the first few passes in the mill—a very hard job to do manually indeed.

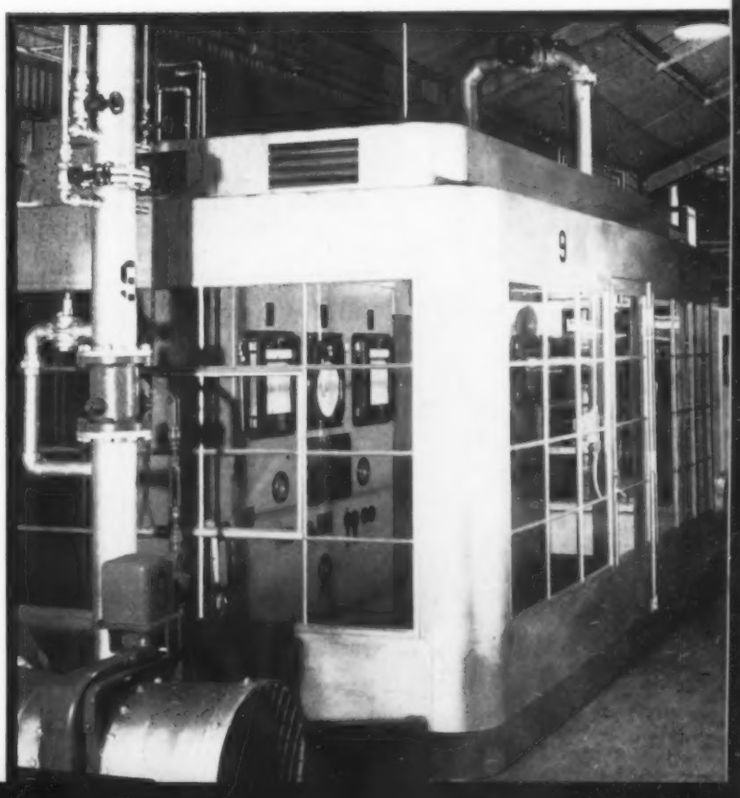
HEAT INPUT REGULATION

This is the most important feature of an automatically controlled pit. In a sense, all of the control equipment comes under this classification; however, for purposes of study, we will consider as the heat input control only that element which reacts first to the indication of fuel requirement.

Heat input to the modern soaking pit should depend entirely on the ability of the steel charge to absorb heat. Since the flow of heat from the ingot surface to its interior requires a temperature difference and, as heat transfer is not instantaneous but requires a time interval, the problem of heat input control becomes rather a complex one, especially where speed of heating is a factor. If the steel is cold throughout, heat can be applied to the surface quite rapidly because conduction away from the surface and towards the interior of the ingot is fairly fast, and the temperature of the surface does not rise too high. As the interior of the ingot becomes hotter, however, the temperature of the outside of the ingot increases in the same proportion—if the rate of heat input stays the same. Since washing and local overheating occurs if the exterior temperature exceeds a certain maximum value, it is necessary to decrease the rate of heat input as this value is approached. Because there is a time factor involved also, the steel is not ready for drawing even though the surface is at the desired temperature. A sufficient interval must be allowed for the interior to be heated to approximately the same value. If it were possible to measure closely enough ingot surface temperature, and regulate heat input so as never to exceed a certain temperature, we would have a good gauge for heat input; however, the practical difficulty of having the temperature element continuously explore the surface of each ingot, together with the difficulty of applying heat to each ingot exactly uniformly top and bottom and on all sides, makes it necessary to use some other gauge for this control. The method in present use involves the measurement of temperature at some particular point within the pit. In some cases, this is the temperature of a thermocouple in the cover, in the sidewall, or in the flue gases leaving the pit or, again, it may be a combination of two of the above. In any case, the temperature of the control point is not the temperature of the steel ingot, but merely relative to combined pit and ingot temperature. This relationship is determinable by test.

The fact that the control point is up to temperature, even after calibration, is not indication enough of itself to show when the steel is properly heated. Another factor must be considered—the actual flow of heat to the pit. If the ingot is uniformly heated throughout and up to pit temperature, it will absorb no more heat; the total heat input under such conditions will be that due to radiation and stack losses only. The calibration of a heat input control then involves the determination of radiation losses and also the exact relative value of the temperature of the control point with respect to steel temperature. If, after charging cold steel, fuel is applied until the control point comes up to temperature,

FIGURE 2—Close-up view of one of the control rooms from the installation shown in Figure 1.



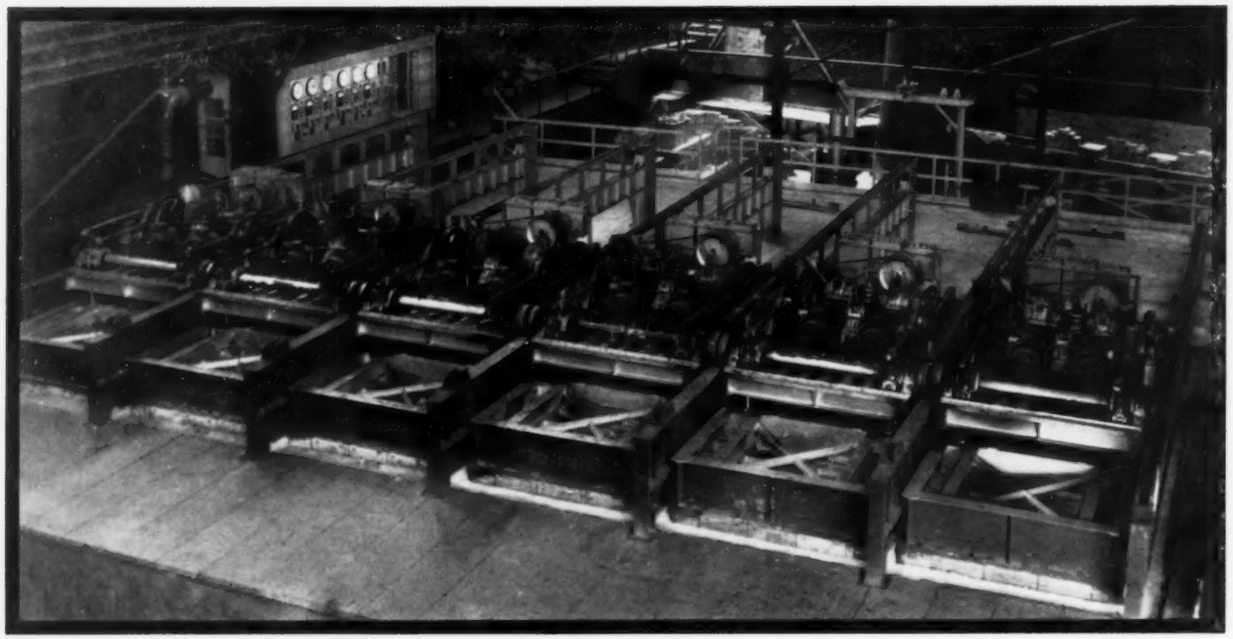


FIGURE 3—General view showing modern soaking pit installation in another plant.

and then, maintaining this temperature, fuel is gradually reduced until heat input becomes constant at a value corresponding to radiation and stack losses, the steel can be assumed to be uniformly heated. To do all of this, and at the same time not exceed the safe maximum ingot shell temperature, is a problem demanding a thorough knowledge of maximum firing rate, ingot placing, and flue gas distribution within the pit. The fact that at times the temperature of the control point is not representative of the steel temperature may lead to difficulty, especially at low firing rates. This is a problem requiring considerably more study.

The rate of heat input to the modern pit can be controlled by primary variation of the fuel flow or the air flow, since fuel-air ratio regulation is always part of the control equipment. If the heat input, or as it is more commonly called, temperature control, varies the rate of fuel input, the ratio control proportions air flow. If the temperature control varies air flow, the fuel-air ratio regulator adjusts the fuel. For variable Btu. fuels, the second method is to be preferred as changes in calorific value are felt immediately by the Btu. correcting mechanism and compensated by a variation in flow, even before a temperature change takes place.

Control of heat input by variation of air flow has another advantage in that a safety factor is present, since on loss of air, due to fan failure or some other cause, fuel is automatically reduced in proportion by the fuel-air ratio control, thereby lessening the danger of explosion.

FUEL-AIR RATIO

It is known that heat is developed only when fuel and air come in contact with each other at a high enough temperature. If too much air is used, too much of the heat is carried away in the flue gas by the stack and, if too little air is present, some of the fuel is not burned completely. For best combustion results, there is a definite ratio of fuel to air which should be maintained at all times. This ratio is not necessarily constant at all firing rates, but it must be consistent at all times, especially if control of heat input is effected by varying air flow from the temperature control. Apart from combustion, the fuel-air ratio regulator has also another important function in soaking pit control. The atmosphere within the pit determines, to some extent, the character of the scale formed on the ingot. With a decidedly reducing atmosphere, the scale formed is thin and tight, adhering to the ingot and rolling into the steel as it passes through the mill. With a definite excess of air, the scale formed on the ingot is loose and porous, and is knocked off completely after the first few passes through the mill. The resulting slab, therefore, has a smooth, even surface which is highly desirable. In addition, the porous scale tends to radiate heat more slowly and the ingot temperature is maintained even while traversing a long path from the pits to the mill.

An important feature in fuel-air ratio control for soaking pits is a means for adjustment to slightly increase the ratio of air to fuel as firing rate is decreased. This becomes more important as the pits become larger and more heavily insulated, and the spread between maximum firing rate and that necessary to supply radiation losses becomes greater. In order to completely burn fuel, it is necessary that the particles of fuel and air come into contact with each other. This contact is a function of velocity and turbulence at the burner. Since the velocity with which fuel leaves most burners is a function of firing rate, this velocity and turbulence decreases, and may become very low at turndown. When this happens, the flame tends to become smoky and it is necessary to supply more air to clear up this condition. The increase in excess air compensates for

the decreased turbulence by providing more air particles for the fuel to contact. In addition to this, an increase in excess air tends to increase the volume of the products of combustion and to lower their temperature, with the result that heat can be transmitted by conduction to all parts of the pit. This effect is along the lines suggested in a previous paper read several years ago before the Association of Iron and Steel Engineers, wherein the author of the paper suggested the use of a combination gaseous fuel, made up of blast furnace and coke oven gases, the relative proportion of blast furnace gas to be increased as the steel temperature approached the desired value in order to keep the pit volume filled out and heat applied to the ingots evenly.

FURNACE PRESSURE

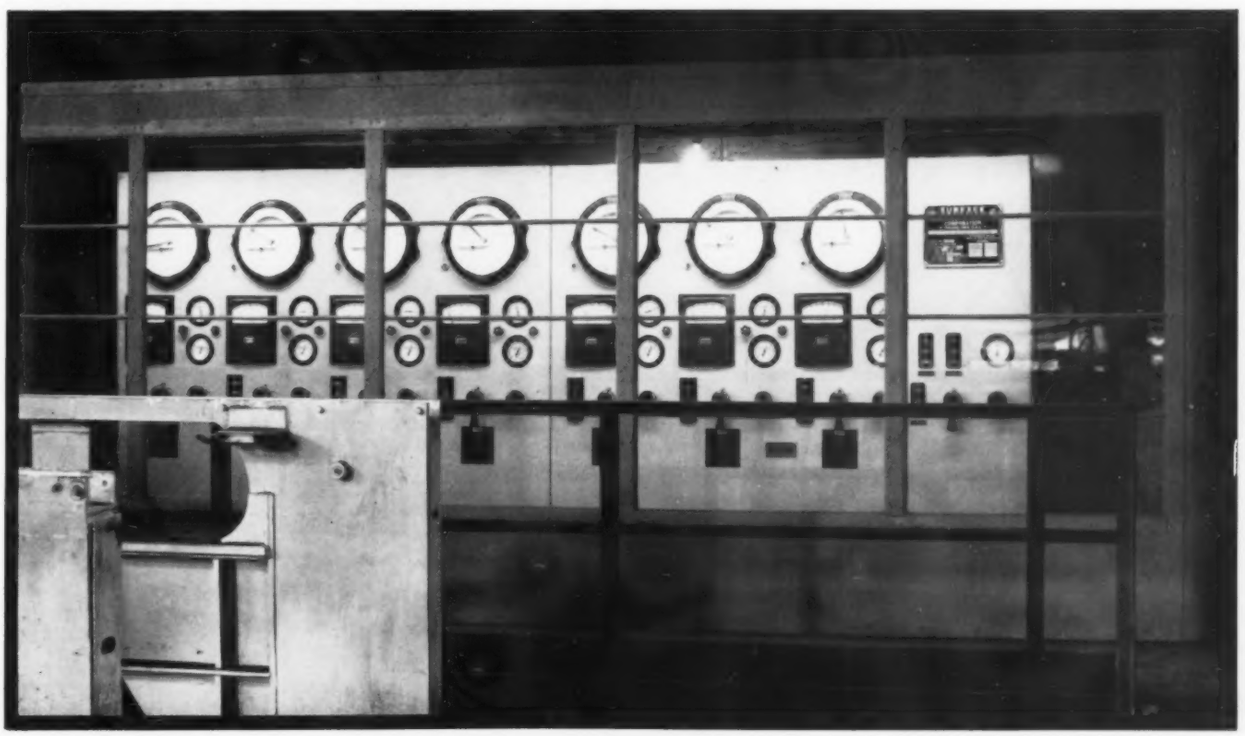
The pressure within the pit chamber is an indication of the balance between the rate of air and fuel input and the rate of gas removal. With the pit in operation, an unvarying furnace pressure indicates that flue gases are removed as fast as they are formed. An increasing pressure shows too slow a rate, and a decreasing pressure, too fast a rate of removal. A regulating device designed to feel this pressure can be arranged to open the outlet damper if the pressure increases and to close the damper if the furnace pressure tends to drop. By properly operating the damper, the opening can be made proportional, exactly, to the requirements, and the furnace pressure can be kept at a constant value at all times.

When furnace pressure control was first applied to heating furnaces generally, it was justified by the savings in the fuel effected by elimination of air infiltration through leaks in the setting, and the reduction of air flow through open ports around burners at low firing rate. In the modern soaking pit, this problem of air infiltration is minimized because of the steel encased construction, and the use of closed forced draft systems of air supply. On the modern pit, there is, however, a greater reason for this pressure regulation. If the outlet damper were adjusted for maximum firing rate and the firing rate reduced, without a corresponding change in damper position, the gases would tend to seek the path of least resistance and would short circuit directly from the inlet to the outlet port, due to excessive draft at the lower firing rate. The steel ingots and portions thereof directly in this path would be overheated, while the rest of the charge would be underheated—obviously, an undesirable condition. By continuously adjusting the damper opening to match the firing rate, the hot gases of combustion tend to completely fill the pit cavity and envelop the ingots at all times, resulting in more even and faster heating. The point from which to control furnace pressure, for much the same reason as with temperature control, depends entirely on the pit design and the method of firing. It is conceivable that it might, in some cases, be desirable to vary the furnace pressure in accordance with firing rate for better application of heat to the ingots.

As a matter of fact, one manufacturer of soaking pits has made several installations where no attempt is made to maintain a constant pit pressure. The operation of the outlet damper is coordinated with the firing rate in such a manner as to produce the desired heating effect on all of the ingots in the pit, with no consideration of the actual furnace pressure.

To illustrate the control principles discussed, the

FIGURE 4—All controls for the pits shown in Figure 3 are mounted in the control house shown here.



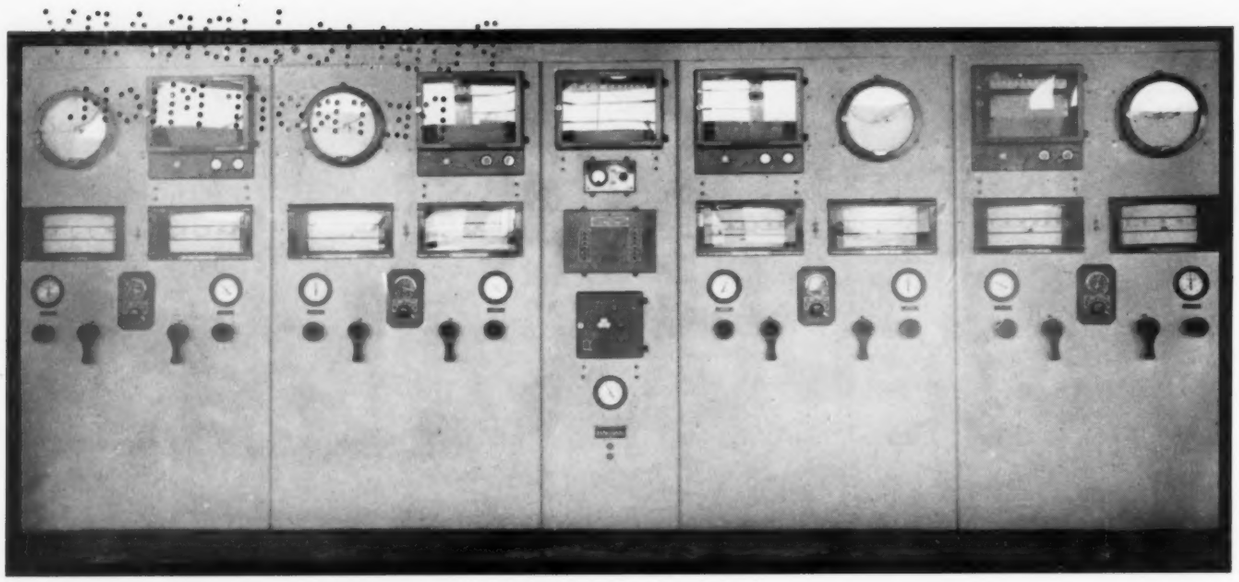
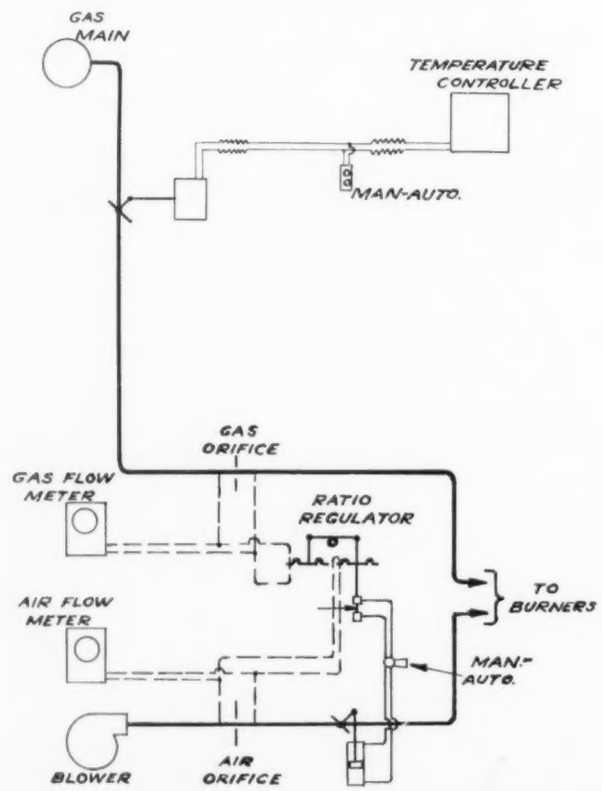


FIGURE 5—Combustion control boards are now similar to electrical switchboards, all controls and instruments being centralized on panel boards.

following figures show schemes that might be used under various conditions. The figures in most cases show only the fuel input and fuel-air ratio control elements. The furnace pressure control, although not shown, is understood to be a part of the system.

Figure 6 illustrates a combined fuel input and fuel-air ratio control for a pit burning a stable gaseous fuel such as natural, coke oven, or blast furnace gas. The rate of fuel input is set up according to the temperature affecting the temperature controller, by regulation of the fuel flow control valve. This valve is opened or closed, depending on whether the temperature measured is lower or higher than the predetermined setting. The gas flow thus established passes through the gas orifice on its way to the burner. The differential pressure created by the orifice is then impressed on the loading diaphragm of the ratio regulator. The regulator, typical of this class of apparatus, consists of a balance beam carrying a movable diaphragm at each end and supported on an adjustable fulcrum at some point in between. The differential pressure created by the gas orifice is impressed on one diaphragm and the differential pressure across the air orifice impressed on the other in such a manner that the higher pressure in each case is above, and the lower pressure below the diaphragm. In this way, the differential pressures across the diaphragms tend to rotate the balance beam in opposite directions. To keep the differential pressures at all times equal, a pilot valve is attached to the beam of the ratio regulator and directs oil under pressure to one side or the other of an oil power piston connected to the air flow control valve. If the differential pressure across the air diaphragm is less than that across the gas diaphragm, the counter-clockwise movement of the beam opens the pilot valve in the direction necessary to open up the air flow control valve, thereby increasing the air flow through the air orifice and building up the differential pressure across the air diaphragm until this pressure is equal to that across the gas diaphragm. When this occurs, the beam moves counter-clockwise until the pilot valve is closed and the power piston becomes stationary. If, now, the differential pressure across the gas diaphragm is reduced, the beam is unbalanced in a clockwise direction and the pilot valve

FIGURE 6—Diagram of combined fuel input and fuel-air ratio control for a stable gaseous fuel.



is moved downward, thereby placing oil under pressure on the oil power piston to close the air flow control valve. The air flow control valve continues to close until the differential pressure across the air diaphragm is reduced to the value necessary to again re-establish the equilibrium of the beam, whereupon, the pilot valve reaches its neutral position and the piston becomes stationary until another movement of the beam calls for power cylinder operation in one direction or the other. In this manner, the rate of air flow is adjusted in accordance with the rate of gas flow. By moving the fulcrum to one side or the other of the center position, the relative differential pressures across the diaphragms necessary to establish equilibrium of the balance beam, and hence the gas-air ratio, may be changed. Movement of the fulcrum, therefore, provides a means for adjustment of ratio.

Figure 7 illustrates a similar fuel input and fuel-air ratio control system, except that in this case the temperature controller sets up the rate of air flow and the ratio regulator adjusts the gas flow in proportion. The control plan of Figure 7 requires that a fuel-air ratio regulator having high sensitivity be used since any irregularity in operation of this control affects not only the fuel-air ratio but also the temperature of the pit. In Figure 6, a similar irregularity in the fuel-air ratio regulator would affect only the furnace atmosphere. In the control scheme of Figure 6, a constant gas main pressure is necessary, whereas in Figure 7, the pressure may vary within considerable limits. In Figure 6, for

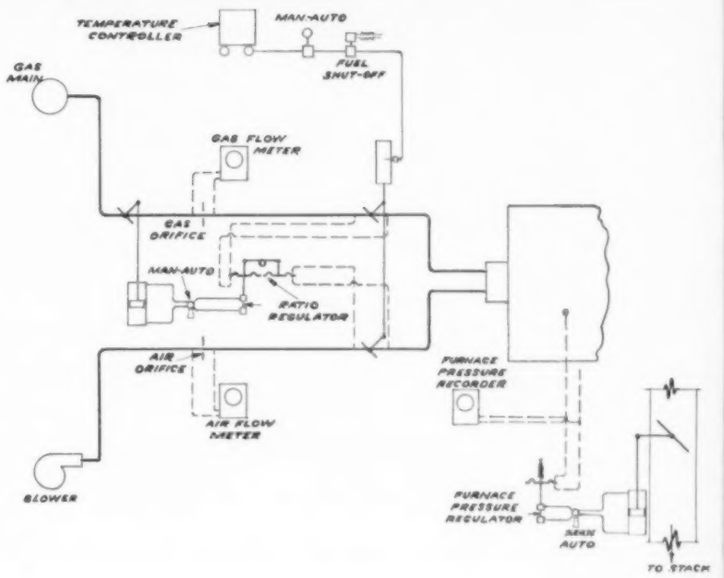


FIGURE 8—Diagram of control system wherein the temperature controller operates both gas and air valves simultaneously.

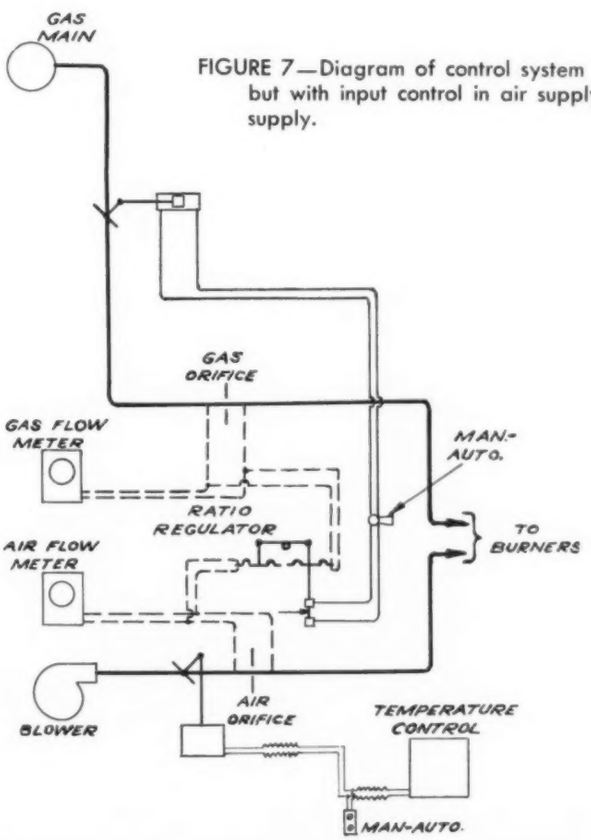


FIGURE 7—Diagram of control system similar to Figure 6, but with input control in air supply instead of in fuel supply.

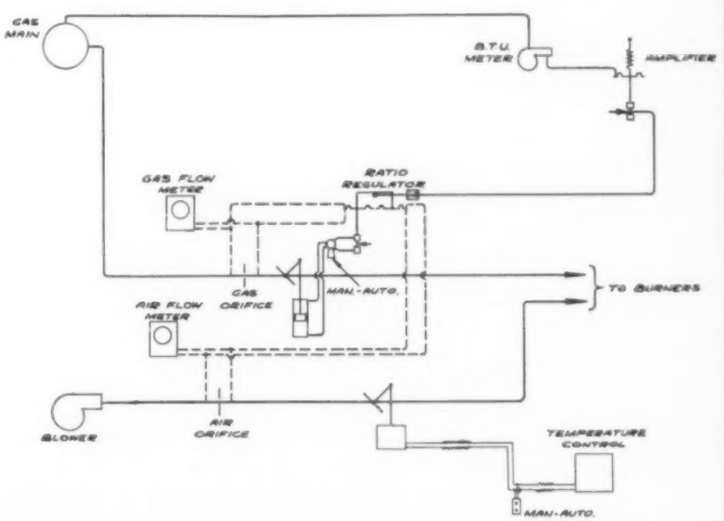


FIGURE 9—This layout illustrates fuel input and fuel-air ratio controls applied for a fuel of varying calorific value.

example, if the gas pressure should rise, the fuel flow to the pit would immediately increase, causing the temperature to rise. The rise in temperature, then, would cut back the fuel flow to the previous firing rate. If, now, the gas pressure in the main should drop, the rate of fuel flow would decrease for the same valve setting and would require a corresponding correction from the temperature controller to re-establish the previous firing rate. In the control scheme of Figure 7, a variation in gas pressure will tend to disturb the fuel-air ratio from that desired, and the ratio regulator will immediately open or close the gas control valve, as necessary, to again re-establish the previous rate of fuel flow. Since the gas-air ratio regulator works instantaneously, whereas the pit temperature requires a certain time interval for a change to become noticeable, the control scheme of Figure 7 will give better results under variable gas pressure conditions. A further advantage of the control scheme of Figure 7 over that shown in Figure 6 is the natural safety interlock provided by the fuel-air ratio regulator. Since the gas flow is controlled from the air flow, any failure of the forced draft air supply will cut off the gas, therefore reducing the danger of an explosion. With the control scheme of Figure 6, should the air blower fail and no auxiliary means for shutting off the gas supply is provided, the temperature would tend to drop causing the fuel flow control valve to open up to its extreme position, flooding the furnace with gas.

Figure 8 shows another type of control layout wherein the temperature controller operates both the gas and air valves simultaneously. This layout is suitable for application where an unusually wide range of turndown is expected, such as for example, a heavily insulated pit handling hot steel, or where on-off or high-low firing is resorted to. In this connection, it might be pointed out that the amount of heat added to a pit is a function of both time and rate of firing. By firing at a constant rate and shutting off the fuel at intervals, the same effect as firing continuously at a gradually decreasing rate, insofar as heat input is concerned, can be attained. The valves shown can be specially characterized of a type as in Figure 14, or can be matched butterfly valves. The fuel shutoff arrangement can be operated manually from the cover operating position, or automatically from limit switches on the cover itself.

Figure 9 illustrates a fuel input and fuel-air ratio control applied to a pit fired by a fuel varying in calorific value. The control shown is the same as that of Figure 7, with the exception that a piston attachment, added to the ratio setting fulcrum of the fuel-air ratio regulator is moved back and forth as necessary to maintain the desired ratio of gas to air. If coke oven gas, for example, were being burned, the ratio of gas to air would be such that 2 cu. ft. of gas would be supplied for every 10 cu. ft. of air. If natural gas were being used, only 1 cu. ft. of natural gas would be required for every 10 cu. ft. of air.

To establish the correct ratio of gas to air, it is first necessary to determine the composition of the gas being used. This may be done by means of a calorimeter or, if a relationship between density and gas composition is known, the density can be measured to give an indication of the gas composition. Having an indication of gas composition and knowing the desired ratio of gas to air, the rest of the problem is a matter of designing suitable apparatus to effect a correction of gas-air ratio, in accordance with the Btu. indication. In the illustration shown, the gas composition determining device is a density meter, which consists of a hollow rotating tube

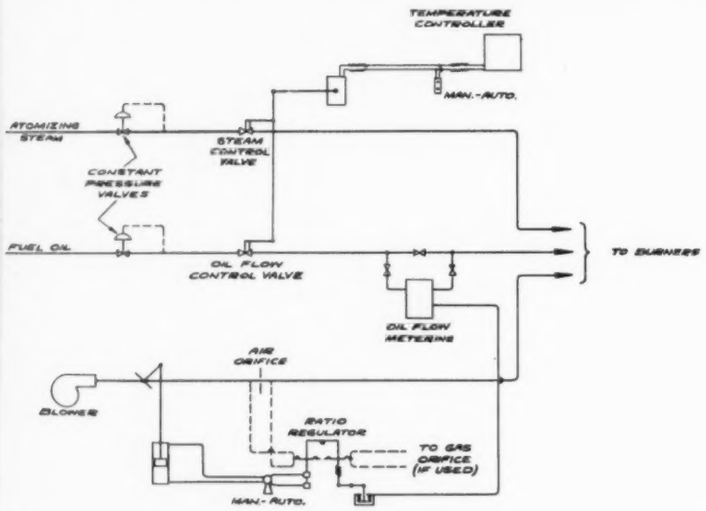


FIGURE 10—Typical soaking pit control using a temperature controlled valve in oil supply to regulate input.

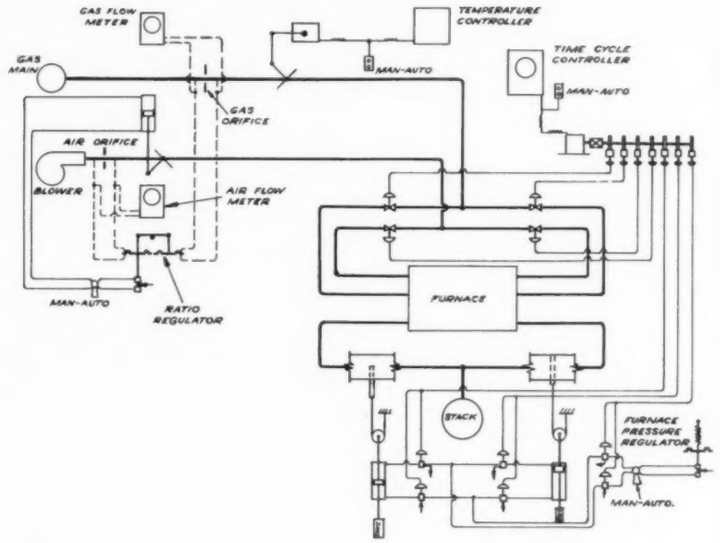


FIGURE 11—Typical control application to a reversing type soaking pit fired by a gaseous fuel.

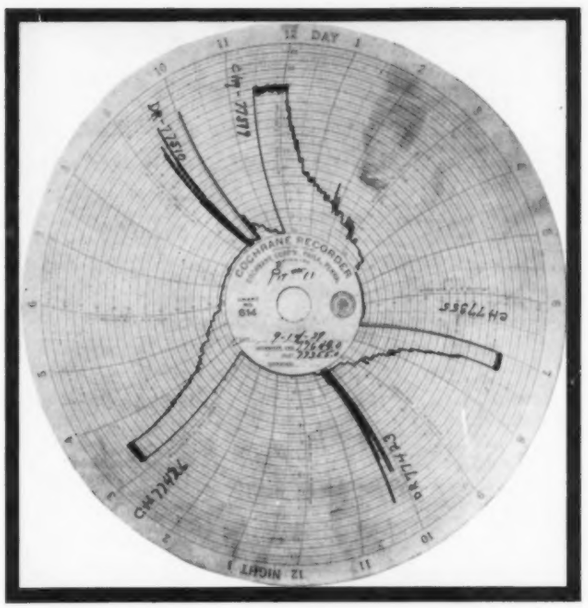


FIGURE 12 *(above)* and FIGURE 13 *(below)* show typical gas flow chart records taken from pits equipped with the control system shown in Figure 9.

through which is passed the gas to be measured. The tube rotates at constant speed and the differential pressure set up between the inlet to the tube and the outlet of the tube depends on the density of the gas being tested. In the case of this meter, coke oven gas establishes a differential pressure of approximately 4 in., whereas natural gas establishes a pressure of approximately 9 in. Various mixtures of the coke oven gas and natural gas in between the two limits provide corresponding differential pressures between these values. This differential pressure is amplified into a control force and applied to the spring-loaded piston to position the fulcrum as necessary to provide the correct fuel-air ratio conditions.

A typical soaking pit control scheme on a pit fired by oil is shown in Figure 10. Here, the rate of heat input is set up by the temperature control which operates a valve in the oil supply line going to the burner. Operating in parallel with this valve by means of linkage is another valve in the atomizing steam line. The linkage is designed so that simultaneous movement of the two valves provides the desired atomizing steam versus oil relationship. Having set up the oil flow, it is necessary to measure this flow and to admit combustion air in accordance with this rate of flow. In the diagram, this is done by means of a measuring device in the oil line which generates an impulse pressure varying as the square of the rate of oil flow. This impulse pressure is then suitably impressed on the balance beam of the fuel-air ratio regulator, and opposed by the differential pressure drop across an orifice in the air flow control line. The ratio regulator sends oil under pressure to a

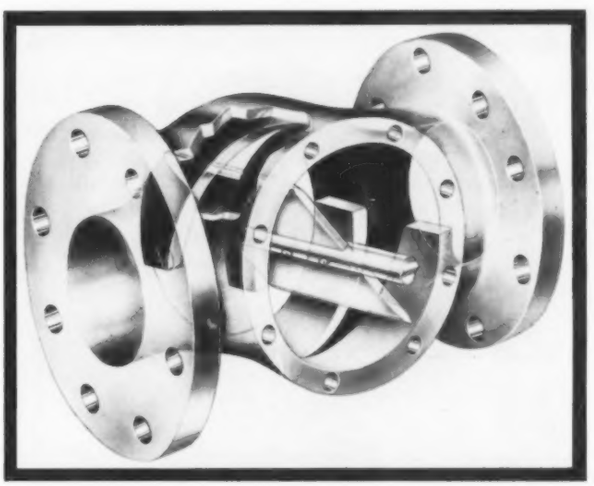
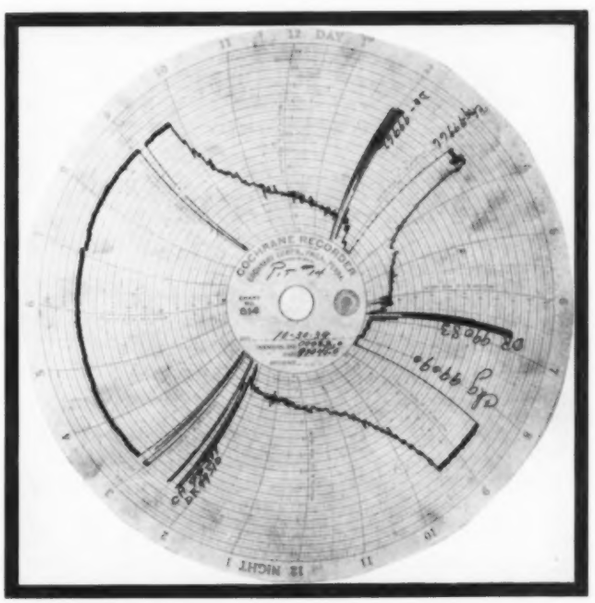


FIGURE 14 —This recently developed V-port butterfly valve gives wide regulation of gas and air flow.



power cylinder regulating the combustion air supply as necessary to maintain this system in balance, thereby providing for the desired ratio of oil to air at all times. This problem could just as easily be handled by regulating the air supply from temperature and proportioning the oil and steam to the air.

Figure 11 shows a typical control application to a reversing type soaking pit fired by a gas fuel. The control scheme on this pit is substantially the same as that shown in previous figures wherein the fuel input is set up by adjustment of the fuel flow, except that on a reversing pit an additional control for rate of reversal is required. Gas and air are directed to opposite ends of the pit by means of spring-loaded diaphragm-operated valves in the gas and air lines. Pressure on the diaphragms opens the valves while release of air pres-

sure allows the valves to close under the action of the springs. It will be noted that the same slide valves in the flues are used to reverse the stack and to regulate the furnace pressure. This is made possible by means of small diaphragm-operated valves which connect the oil power cylinders to the regulator lines when pressure is impressed on the diaphragms, and to the oil pressure and drain headers when pressure is released. The various valves are operated in correct sequence by a program control which consists of a motor-driven camshaft operating a series of pilot valves. The valves supply pressure to the diaphragms of the reversing units as necessary. A time cycle controller is a part of the reversing system and permits the time of firing to be adjusted independently for either end of the pit. The reversing system shown can be operated manually or automatically with the heat input and ratio controls under manual or automatic control.

Figures 12 and 13 show gas flow chart records taken from pits equipped with the control shown on Figure 9. Note, particularly, the wide range of firing. Figure 14 shows a recently developed V-port butterfly valve suitable for regulation of gas and air flow over the wide ranges in firing rate shown in the previous illustrations.

DISCUSSION

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J. R. GREEN: Some further comments, particularly on the temperature control phase of the problem, should be of value by stating the fundamentals involved in soaking pit temperature control as well as what has been accomplished to date and what may be striven for in the future. Boiled down to essentials, two things should be done by a temperature control system on soaking pits:

First: Maintain the maximum heat head, or heat potential, which will not cause any washing or other physical defects of the ingots, thus providing the maximum safe heating rate.

Second: Deliver the ingots from the pit at the desired rolling temperature (which is normally different than the maximum safe heating temperature).

The first of these requirements may, in the case of alloy ingots, call for a series of intermediate maximum temperatures and soaking periods in order to provide safe metallurgical or physical treatment.

The actual and practical measurement of these desired temperature conditions is the next stage in the problem. Ideally, a measurement of skin temperature of the ingots exposed to the highest flame temperature in the pit would be the best answer to the maximum safe heating temperature. Unfortunately, due to physical problems and difficulties in reading solid metal temperatures through flame atmospheres, it is not as yet possible to secure these skin temperatures during heating by contact or radiation means.

It is, therefore, necessary to measure temperatures at some location in the pit which is related to the maximum possible ingot skin temperature, and which protects the measuring element from mechanical breakage or "pocketing" under any loading condition. This location depends largely upon pit design and method of firing. In some designs it is desirable to secure an average of the temperatures at several locations to provide a margin of safety.

The exact measurement of the average ingot temperature when soaked is also at present impractical to secure by methods such as are used, for example in sheet annealing where thermocouples are located in the charge itself. Again a compromise location must be selected which is most indicative of the average steel temperature. Depending upon pit design, this location may be outlet flues, pit bottom, or even the same point as used to measure the safe maximum temperature. With the latter condition it is obviously necessary to progressively lower the control point either manually or automatically during the course of each heat in order to provide both maximum safe heating rate and desired final ingot temperature. As to the methods of securing these temperatures, either rare metal thermocouples or radiation units are suitable and either type is amply responsive, for control by comparison, to the masses of the pit and its charge.

Since the fuel requirements continuously decrease during the progress of a heat, due to the decreasing ability of the charge to absorb heat, it is desirable to automatically lower the fuel input and still maintain the exact desired temperature. This characteristic in a control system is known in the jargon of control manufacturers as automatic reset or droop correction and is available in both electrically and air operated equipment, the latter being somewhat simpler from a design and equipment standpoint.

Assuming that the pit design provides points of temperature measurement fairly representative of maximum safe skin temperature and average soaked ingot temperature, the ideal temperature and fuel curves for a heat can be represented by a graph, corresponding to a continuous strip chart.

Starting with either a hot or cold charge of any but alloy ingots the pit is heated to the maximum safe temperature with the highest fuel rate for which the pit is designed. Actual skin temperatures as well as indicated average and actual minimum temperatures will lag behind at lower values. As the pit is held at the maximum safe heating temperature, fuel input is gradually reduced, actual skin temperatures gradually increase, followed by indicated average ingot and actual minimum ingot temperatures. As the indicated average temperature reached the desired delivery temperature it is possible to automatically transfer the control to this indication, still further reducing the fuel input in keeping with the ability of the ingots to absorb heat,

but retaining a high limit on the safe heating temperature.

Under this condition of firing the actual skin temperature approaches the desired finishing temperature and actual minimum approaches the indicated average temperature until both actual values are equal. Since these conditions are measurable only in relative values the best operating guide for completion of soaking is found from the gradual decrease of the fuel input to equal the radiation and stack losses. If desired a signal system in the flow meters can be incorporated to indicate the condition where the fuel rate is just equal to radiation losses from the pit.

In order to maintain the desired temperatures during drawing operations it is also desirable to automatically transfer control of fuel input to maximum safe control point in order to recover average temperatures as rapidly as possible between each ingot removal.

These ideal conditions are being closely approached in actual practice, and although improvements will undoubtedly be made in apparatus and methods of temperature measurement and control the fact remains that modern design of pits combined with temperature, combustion, and pressure control are delivering ingots to the mill with fewer physical defects, at more uniform rolling temperature, and at a reduced fuel cost.

E. E. Callinan: I was especially glad Mr. Boho brought out the point of the use of excess air at low firing rates, and the prevention, as much as possible, of any tendency for gases to short circuit. This is a very important point, to my mind, in securing uniform heating.

I might mention that there are two other factors which contribute to the prevention of short circuiting. It is very important to have specific locations for your ingots in the pit. That is, they must be distributed in such a way that there will be no tendency for certain definite paths to be formed. I think it is very important, when you have charges of varying size going into the pit, that the setting of the ingots in a pit be predetermined in such a manner as to minimize any tendency for short circuiting.

Another factor which enters into this is the design of the pit itself with respect to the outlet ports. It used to be common practice to tend to overdesign a pit; that is, with respect to certain critical port areas, and so forth. With the modern design of pits, this is being given more attention, and the ports are so designed that they will be adequate to take care of the maximum firing rates, but still not oversize. If they are not oversize, there will be less tendency for short circuiting to occur.

I would like to ask Mr. Boho what advantages there may be in the control of pressure by firing rates as against the regular practice of controlling the damper by the pressure impulses within the pit.

W. T. Dean: I am wondering if the remarkable success of the modern pit isn't very largely due to the use of automatic control. In most plants throughout the country we have relied upon a heater to handle three or four rows of four-hole pits by hand. He has sixteen furnaces, you might say, to look after. It is physically impossible. There isn't time enough for a man to give those sixteen holes anything like the correct attention as to mixture of fuels and temperatures that can be obtained with automatic control. The development of these new pits in the last five years has come simultaneously with the development of automatic control, and I wonder if the marvelous success of these pits hasn't been largely due to automatic control, rather than to the specific design of pits.

The large pits, it appears to me, have been forced by the cost factor to quite an extent. You can build two large pits cheaper than you can build four small ones, when you consider all the automatic controls that should be applied to the smaller pits. On the subject of the size of the pit, I think in a great many cases we have gone too far. We have put too many eggs in one basket; we tie up too much of our capacity. I think there is a compromise somewhere between the old, small pit and the present pit that holds 20 or 25 small ingots, or 12 or 15 large ingots.

These matters, I think, would stand a little wider discussion. I wonder if there is a limiting size. What is the proportion of the control equipment to the total cost of an installation? Is it a controlling factor?

On the location of thermocouples, roof, flues or side walls, I have noticed some users have dropped the roof thermocouple entirely. Others have dropped the flue thermocouple. Others have relied entirely on the wall thermocouple. I wonder if anybody has tried to do what has to be done in gun furnaces, for instance. I remember a case of a gun furnace where we had to put in five thermocouples contacting the barrel. The tube manufacturers might bring out a means of retracting couples.

The difficulty all around lies in the calibration of the heat input, and that, again, hinges on the location of the couples and those inherent variables which have been brought out here clearly. The number, the size, and the location and temperature of the ingots also enter into the calibration of heat input.

We had pretty good heating in a lot of the old pits whenever we had time enough to take care of them properly. I have seen some cases where old pits have been equipped with automatic control in the same plants with modern pits, and I don't believe anyone at the rolls could tell which pits were drawn.

I would like to hear something about the value of highly luminous flames, compared with the ideal mixture. How far dare we go from the ideal in order to get the desired scaling of the ingot, bearing in mind that when we do that we are throwing fuel up the stack with that 80 per cent nitrogen?

I would like to hear a frank discussion of the operating difficulties, to help the man who has to live with these controls day and night, including Sundays, while the manufacturers' engineers are out enjoying the more abundant life. What happens when the gas lines are clogged; what to do when the orifice goes foul, with no shutdown in sight; when sudden changes develop, such as wind pressure, barometric pressure, and wind direction; last, has anyone developed a simpler method of control?

F. D. Burne: There was one detail on Mr. Boho's schematic diagrams, particularly on the Figures 6 and 7. I noticed the gas measuring orifice is placed on the down-stream side of the gas valve. Is that actually

(*Please turn to page 53*)

NEUTRAL GROUNDING *in A-C. Systems for Steel Mills...*

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MILWAUKEE, WISCONSIN

Presented before A. I. S. E. CHICAGO DISTRICT SECTION, April 9, 1941

▲ NEUTRAL grounding in a-c. distribution systems has been a widely discussed subject over a period of many years. But it was not until recently that general application of neutral grounding to steel mill systems began to be seriously considered. Perhaps the most striking characteristic of a modern steel mill is the imperative need for exact scheduling of the various operations. The efficiency of a mill and the ability of the installed equipment to earn a return on its investment depend upon a degree of coordination in which frequent outages cannot be tolerated. In the early days of power transmission, it was this same desire to prevent outages that discouraged any thoughts of neutral grounding. Power systems were not extensive and voltages were low, and it was probably true that grounding would have made very little difference anyway.

As systems grew larger and transmission voltages increased, evidence began to appear of excessive over-voltages, particularly during single line to ground faults. It is of interest that the utilities of the Chicago area were among the first in the country to ratify grounded neutral operation after an investigation indicated that overvoltages could be reduced in this way. That operating data were meager and conflicting is borne out by the fact that other localities were very slow to follow. In fact, it was not until fifteen years later that New York finally followed suit. At the present time, a safe estimate of the number of power companies still operating with isolated neutral would be about ten per cent.

It is realized that opinions in the matter of neutral grounding in steel mills may differ sharply, and so the present paper will endeavor to review briefly, from an impartial standpoint, the various factors and arguments on both sides that should constitute the basis of any neutral grounding policy. The general principles will be considered in the light of their specific bearing on steel mill systems, and the various grounding methods will be compared.

FIGURE 1—Tabulation of over-voltages possible under the different theories advanced in this paper.

THEORY	VOLTAGE E_b.
I	INFINITE *
II	(5.5 to 7.5*) x E_n.
III	3.5 x E_n.
FUNDAMENTAL VOLTAGE	$a\left[\frac{(1-a)Z_2 + (1-a^2)Z_0}{Z_1 + Z_2 + Z_0}\right] E_n$.

*No Damping.

GENERAL CONSIDERATIONS

The fundamental difference, from the operating standpoint, between a grounded and an isolated neutral system is, of course, the manner in which accidental grounds are detected and disposed of. The proponents of isolation believe that immediate clearing of grounded circuits is not always to the best interest of service continuity, especially with reference to such important circuits as the main pump house, the open hearth department, main drive motors, etc.

Many schemes for detecting grounds on isolated neutral systems have been employed. Perhaps the simplest of these consisted of two potential transformers with primaries in series across two of the lines with midpoint grounded. The secondaries served two voltmeters, plainly visible on the switchboard, which indicated the presence of a ground and also which phase was grounded. The exact location of the ground, however, involved an elaborate routine procedure and was essentially a trial and error process.

Relaying methods have also been proposed for isolated neutral operation, as for example: the ground selector,

the thyrite resistance coupled relay, the zero sequence voltage relay, and others. In order to utilize the principal object of isolation, from the steel mill viewpoint, *i.e.*, to maintain service on a grounded feeder until repairs can be conveniently made, some of these schemes may be arranged merely to indicate the approximate location of the ground rather than to automatically clear the grounded circuit.

Indeed it is seriously questioned by the neutral grounding advocates whether these methods can be trusted to clear the minimum grounded area in the frequently complicated distribution networks of large steel mills. While a fairly high degree of selectivity is claimed for some of these devices, it is generally agreed that the accurate relaying possible with grounded neutral has not yet been achieved.

With grounded neutral, most of the different types of relays ordinarily employed may be arranged to operate as ground relays. Being energized from the neutral return lead of the three line current transformer secondaries, there is no lower limit setting dictated by the violent power swings and load fluctuations normally encountered in steel mill systems. As a result they are very sensitive to ground current, functioning quickly and accurately on values of the order of full load current or even less.

The reasoning in support of immediate clearing of grounds is based upon the belief that with the provision of alternate sources and routes of power supply to the important load centers, continuity is best served by confining the disturbance to the smallest possible area. Its major premise is concerned with the destructive over-voltages that may result due to operation with a ground on one phase.

When one line of an isolated neutral system becomes grounded, the charging current of the system will flow into the fault. If the contact is solid, the grounded phase tends to approach earth potential while the other two increase to full line voltage to ground. However, if the contact consists of an unstable arc, it has been known for many years that excessive voltages may appear on all three lines. Several theories have been advanced in explanation, all of which depend upon the negative resistance characteristics of the arc, and on the ability of the system to retain a charge between the extinction and restriking of the arc. The principal differences consist in the manner in which the arc is controlled and the maximum voltages possible.

Briefly stated, one theory which we may call theory I, assumes the arc alternately strikes and breaks every half cycle at the peaks of the high frequency oscillatory voltage wave. If damping is neglected, the voltage may increase indefinitely. Theory II, proposed by Petersen, assumes the striking of the arc at the peak of the fundamental voltage and its extinction at the first zero of the high frequency oscillatory current. Under these assumptions the faulted phase may reach a theoretical maximum voltage to ground of six times normal, and the two unfaulted phases a corresponding value of seven and a half times normal. The effect of damping, however, will be to limit the maximum value to about five and a half times normal. Theory III assumes both the striking and extinction of the arc to be controlled by the fundamental frequency voltage, with a maximum voltage of three and a half times normal for a three phase system.

In all cases, if system neutral is grounded, the charge will be drained off and according to theoretical considerations the possible overvoltage is a function of the neutral impedance. This is borne out by observations

FIGURE 2—View showing transformer under test to determine its characteristic surge impedance.

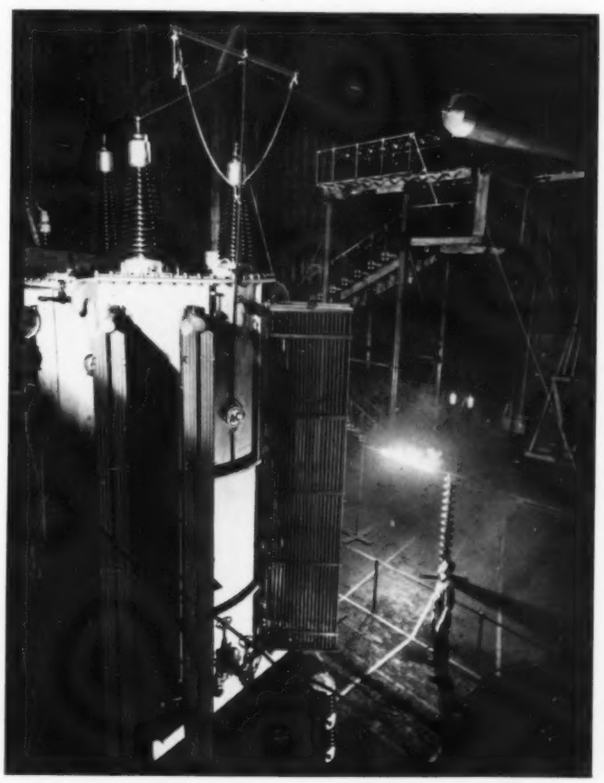
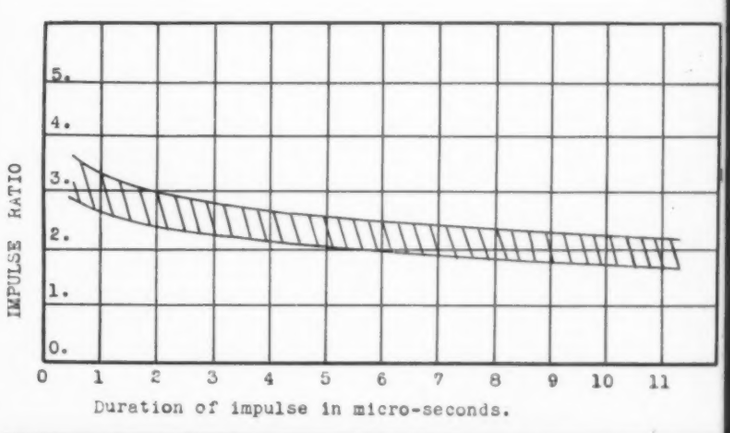


FIGURE 3—Curve showing variation of impulse ratio with duration of impulse before breakdown may occur.



made by project committee 2J of the Edison Electric Institute on the systems of several power companies under various neutral conditions.

Examination of the test data in the light of these theories as presented in the Edison Electric Institute Engineering Report No. 30, reveals that in most cases the arc appeared to be fairly steady and of fundamental frequency. Thus none of the proposed theories apply since they all assume arc instability. A few cases, however, did show instability of the arc and some evidence to partly confirm both theories II and III, although the gradual building up of the sound phase voltages with successive restrikings was not observed.

These data are by no means conclusive since surge recorders used in the same tests indicated voltages of 5.4 times normal, whereas the highest value recorded by oscillograph was 3.9 times normal. They do seem to indicate that all arcing grounds do not result in cumulative oscillatory voltages, which is not in the least contrary to theory.

Figure 1 shows a tabulation of the over-voltages possible under the different theories, and also the fundamental voltage on a sound phase during a single line to ground fault determined by means of symmetrical components. It will be observed that entirely apart from any arcing ground phenomenon, if resistance is neglected and it so happens that the zero sequence reactance is nearly equal to and opposite in sign from the sum of the positive and negative sequence reactances, the expression for the fundamental voltage becomes very large.

The severity of arcing grounds and attendant overvoltages in the average steel mill will depend upon the extent of the system together with voltage employed. Evidence of this phenomenon usually takes the form of one or more insulation failures simultaneously with or soon after a line to ground fault. Such cases have been observed on small 6600 volt steel mill systems and will in general be more frequent, the larger the system. It stands to reason that high dynamic voltages, due to arcing grounds, should not be as prevalent in steel mills as on high voltage utility power systems.

The chief causes of insulation failure in steel mills are lighting and switching surges. While the subject of protection from these sources is in itself very broad, it concerns us only insofar as it influences neutral grounding policy. Theoretically, grounding of the neutral should normally make no material difference in the possible magnitude of surge voltages. In an isolated system, however, if one line becomes grounded, the possible voltage from a switching surge will be 73 per cent higher than for a grounded neutral system. The maximum values commonly attributed to switching surges would then be four times normal for grounded operation and seven times normal for isolated neutral operation.

In many steel mills power is transmitted at generated voltage. It is generally agreed that a grounded neutral generator is easier to protect against surges because reflections at the neutral and consequent doubling of the incoming wave is avoided. From the standpoint of surge protection, it has been shown* that a neutral resistance equal to the parallel surge impedance of the three phases of the generator will not only prevent reflection, but will damp out any internal oscillation as well. Any resistance below this critical value will prevent increased voltage to ground, but is less effective in reducing abnormal stresses between turns.

The characteristic surge impedance of electrical apparatus may be determined by impressing a standard surge voltage wave with the aid of the 3,000,000 volt impulse generator of Figure 2, which shows a transformer under test.

As an indirect benefit, the lightning arresters on a well grounded system may be designed to limit the voltage to about eighty per cent of that for an ungrounded system. Consequently they will be smaller and cheaper and will provide better protection for the system.

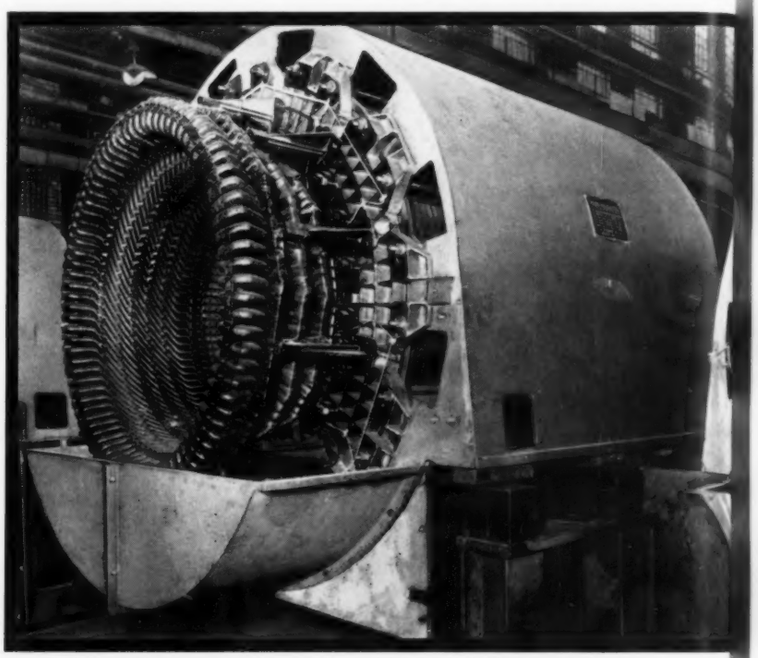


FIGURE 4—View showing manner of bracing end windings of large generator to insure against injury from short circuit stresses.

Closely related to the effect of surges is the cumulative damage of insulation with repeated voltage stresses of short duration. Referring to Figure 3, it is well known that impulse voltages considerably greater than the sixty cycle crest break down voltage may be impressed upon electrical machines before breakdown will occur. Below this value for which a single impulse will cause breakdown, there is a second point for which an infinite number of impulses are required to cause failure. The region between these two limits represents values of impulse voltage for which some permanent injury results from each impulse.

With this in mind, it is evident that the ability of equipment to withstand overvoltages cannot be gaged entirely by its past performance. On the contrary, the conditions imposed upon insulation in a steel mill are most severe. There is perhaps no other industry in which the major load units are subjected to the frequent switching of steel mill motors. In addition, the load and

*"Voltage Oscillations in Armature Windings Under Lightning Impulses," E. W. Boehne, *A.I.E.E. Trans.*, October, 1930, page 1587.

temperature variations coupled with extended periods of shut down tend to promote moisture absorption in locations where abnormal humidity exists. These considerations point to the importance of limiting the possible overvoltages by every available means.

The directly fed distribution systems in most steel mills have relatively short lines and hence low inherent impedance. If no feeder reactors are used, the generator reactance will largely determine the magnitude of short circuit currents. In such cases the zero sequence reactance will be quite low, especially for turbine generators, and for a solidly grounded neutral the subtransient short circuit current may be fifty per cent greater for a line to ground fault than for a three phase fault.

The mechanical stresses in the windings for this condition will be greatly increased and adequate provision must be made against coil distortion due to these enormous forces. Figure 4 shows the manner in which the end windings of a 40,000 kva. steel mill turbine generator are braced in order to insure against injury or movement under the severe short circuit stresses of a line to ground fault. The heavy non-magnetic brackets, to which the coils are securely lashed, provide liberal support at numerous points distributed over the entire end portion of the windings. While the windings of all modern machines must be braced to withstand a dead line to ground short circuit, it is generally regarded as good policy to avoid these unnecessary strains when possible. The same argument holds true for bus and line supporting structures throughout the system.

Moreover, the cost of circuit breakers for large low reactance systems is no small item, and if a fifty per cent margin in interrupting capacity is required, an appreciable addition may be expected. When grounded neutral operation is used, it would be desirable from the circuit breaker standpoint to use a neutral impedance which would limit the ground fault current to the same value as the three phase short circuit current. In this way no increase in rupture capacity is required.

The correct value of neutral reactance or resistance to accomplish this may be derived with the aid of symmetrical components by equating the expressions for single line to ground and three phase short circuit currents in terms of the sequence reactances. This has been done for the current in a generator whose neutral is grounded and which operates in parallel with other ungrounded machines. The results are shown in Figure 5.

Another important consideration is the effect of excessive short circuit current on stability. The major portion of system faults starts as line to ground faults, and if heavy currents are permitted to flow, serious voltage dips and consequent instability may follow. Generally speaking, the synchronous machines in a steel mill will maintain synchronism provided a drop in the positive sequence voltage of thirty per cent is not exceeded. Up to about twice full load current may ordinarily be allowed in a properly designed system without transgressing this safe limit. To keep the line to ground short circuit current down to about full load value or thereabouts, would appear to give an ample margin of safety from the stability standpoint. At the same time, physical damage at the point of the fault would be minimized.

If two or more generators operating in parallel have their neutrals grounded, the triple harmonic voltages will circulate current in their windings. The magnitude of each harmonic current will depend upon the vector sum of the corresponding harmonic voltages in the machines and the sum of the zero sequence reactances multiplied by the order of the harmonic. The higher triples as ninth, fifteenth, etc., become progressively smaller generally, and because of the increasing reactance with frequency, the circulating current will usually be mainly third harmonic.

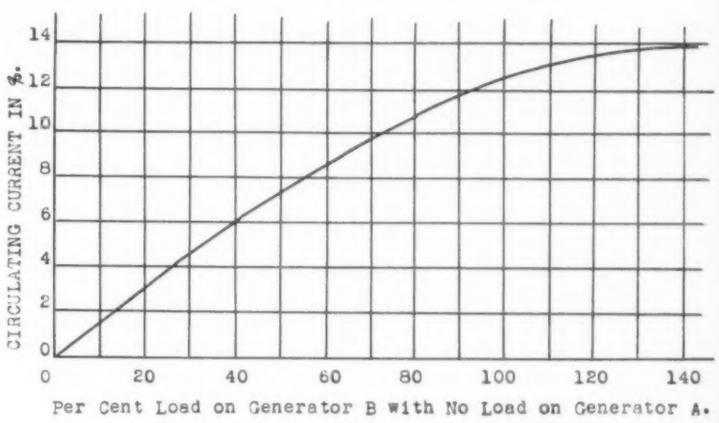
If two duplicate machines are paralleled and both grounded, their harmonic voltages will be equal and opposite as long as both machines are equally loaded. With no load on one machine, the circulating current will vary with the load on the other similar to the curve of Figure 6. For the two machines considered, slightly over twelve per cent of rated current will circulate with

ARRANGEMENT	NEUTRAL RESISTANCE	NEUTRAL REACTANCE
K Machines in Parallel	$\frac{1}{3}\sqrt{\left[X_{1\text{-}1}+X_{P\text{-}1}+\frac{X_{1\text{-}1}X_{P\text{-}2}}{X_{1\text{-}2}}\right]^2-X_{P\text{-}\phi}^2}$	$\frac{1}{3}\left[X_{1\text{-}1}+X_{P\text{-}1}+\frac{X_{1\text{-}1}X_{P\text{-}2}}{X_{1\text{-}2}}-X_{P\text{-}\phi}\right]$
K Duplicate Machines	$\frac{1}{3K}\sqrt{\left[(K+2)X_{1\text{-}1}\right]^2-\left[X_{1\text{-}1}+X_{1\text{-}2}+KX_{1\text{-}0}\right]^2}$	$\frac{1}{3K}\left[(K+1)X_{1\text{-}1}-X_{1\text{-}2}-KX_{1\text{-}0}\right]$
2 Duplicate Machines	$\frac{1}{6}\sqrt{\left[4X_{1\text{-}1}\right]^2-\left[X_{1\text{-}\phi}+X_{1\text{-}0}\right]^2}$	$\frac{1}{6}\left[3X_{1\text{-}1}-X_{1\text{-}2}-2X_{1\text{-}0}\right]$
Single Machine	$\frac{1}{3}\sqrt{\left[3X_{1\text{-}1}\right]^2-\left[X_{1\text{-}\phi}\right]^2}$	$\frac{1}{3}\left[3X_{1\text{-}1}-X_{1\text{-}\phi}\right]$

Where: $X_{1\text{-}1}$=Positive sequence reactance of grounded neutral machine.
$X_{1\text{-}2}$=Negative " " " " " " "
$X_{1\text{-}0}$=Zero " " " " " " "
$X_{1\text{-}\phi}$=Sum $X_{1\text{-}1}+X_{1\text{-}2}+X_{1\text{-}0}$
$X_{P\text{-}1}$=Positive sequence reactance of all machines in parallel.
$X_{P\text{-}2}$=Negative " " " " " " "
$X_{P\text{-}0}$=Sum $X_{P\text{-}1}+X_{P\text{-}2}+X_{P\text{-}0}$

FIGURE 5—Neutral impedance for equal single line-to-ground and three phase short circuit currents.

FIGURE 6—With no load on one machine, circulating current varies with load on the other machine as shown here.



full load on the loaded machine, while the maximum value of fourteen per cent applies at 140 per cent load. Inasmuch as the resultant rms. current is the square root of the sum of the squares of the load current and the circulating third harmonic, there is very little increase in stator copper temperature. However, the zero sequence circulating currents may tend to set up vibration, noise, or some additional rotor heating. For this reason it is common practice to ground only one machine in a station and to provide for transferring the ground connection to some other machine when the one machine is taken out of service.

The balanced harmonics in an a-c. system, *i.e.*, those not a multiple of three, are 120 degrees apart in the three phases and hence their vector sum is very nearly equal to zero. If the three lines are reasonably close together, they will not usually induce objectionable noise in parallel telephone lines in view of the short lengths likely to be exposed in a steel mill. The triple harmonics, on the other hand, are in phase on the three lines and if neutral is grounded, the currents will flow out on all three lines in parallel, through the line capacitance to ground and back through the neutral connection. The inductive coupling for this arrangement may be as high as forty times that for the same current flowing in three phase relationship.

Nevertheless, serious cases of interference as a result of normal operation with grounded neutral are rare in steel mills, and when they do occur may be overcome at moderate cost by the use of a resonant selective device. Under short circuit conditions, however, excessive ground currents may result in severe shock in exposed telephone circuits with accompanying hazard to life and property. This can of course be reduced by proper precautions, but in general constitutes another good reason for limiting ground fault currents to a low value.

The practice of connecting potential transformers in star with neutral point grounded on an otherwise isolated system, has been found in certain cases to give rise to serious over-voltages. The combination of unequally saturating transformers and the capacitances of the system may under certain conditions, as during switching operations, result in neutral instability and voltages of two to three times normal. While neutral inversion, as this is called, can be avoided by grounding of the generator neutral, several other methods are also possible even if the potential transformer neutral cannot be conveniently isolated. A loading resistance across the potential transformer secondary, or a damping resistor in the open delta of a tertiary winding will accomplish the same result.

METHODS OF GROUNDING

In comparing the different grounding methods it is necessary to consider the particular qualities each method will impart to a steel mill distribution system. A logical starting point, therefore, is first to review briefly the condition of isolated neutral operation.

While selective relaying of ground faults is not practicable, many operating departments feel that it is neither necessary nor desirable if important circuits are to be kept in service temporarily with one line grounded. When operating in this way the line to line voltages will normally be unaffected, but the neutral will be so displaced that the voltage to ground on the two sound phases will be increased 73 per cent. As all equipment is insulated from ground for full line to line voltage, there is no serious hardship in this connection, provided this voltage is not exceeded due to arcing grounds, surges, neutral inversion, etc.

Unfortunately, the relatively unimportant circuits cannot be cleared either, and on the basis of both theory and observation, the continued operation of a grounded feeder may result in another fault and short circuit, possibly in some important machine. Thus an entirely avoidable, costly outage has resulted.

If it can be assumed that system is small enough so that over-voltages due to arcing grounds are infrequent, it will be true that the isolated system will have fewer short circuit disturbances. When they do occur, however, they will be more difficult to control and relay accurately than a line to ground fault with grounded neutral. Circuit breaker interrupting capacity and mechanical forces during faults are limited to the three-phase short circuit values. Telephone interference disturbances are minimized both for normal and short circuit conditions, but protection against internal surge reflection is not present. The flexibility of transformer connections without danger from third harmonic and the feasibility of open delta operation in the event of the failure of one transformer are both good arguments favoring isolated neutral operation.

Assuming that grounding of the neutral is preferred, the question of how to ground must next be answered. To avoid the expense of special neutral grounding equipment, solid grounding appears attractive at first glance. Under this condition, selective relaying is assured and over-voltages are held to a minimum.

On the other hand, the excessive short circuit currents characteristic of the low reactance systems in steel mills, will require elaborate precautions against mechanical forces and will result in severe burning at the point of fault. More costly circuit breakers and frequent bad voltage dips and instability also go hand in hand with solid neutral grounding. In the event a line to ground fault does not clear, the large sustained current may prove injurious to the grounding unit.

Telephone interference conditions are highly unfavorable, and while internal positive surge reflections are prevented, oscillations may occur stressing the insulation between turns. Furthermore, in large systems, considerable displacement of the neutral takes place due to the heavy current flowing through the inherent ground resistance. By the same token, dangerous potentials may occur on the frames of internally faulted load machines due to the frame grounding resistance.

It may be mentioned here that the importance of good solid ground connections of frames cannot be overemphasized from the standpoint of safety.

In order to limit the destructive ground current, a resistor may be inserted in the neutral ground connection. With ground relays, a resistance sufficient to reduce the ground fault current to a predetermined moderate value may be employed without sacrificing rapid selective clearing of grounded circuits. The re-

duced ground current will in turn afford a great reduction in mechanical stresses, smaller voltage dips and fewer outages due to loss of synchronism. Additional benefits are: smaller circuit breaker rupture capacity, reduced burning at the point of fault, and reduced danger of injury to the grounding machine in case of relay failure. Although the neutral may shift as much as 58 per cent of line to line voltage, the maximum frame potentials of faulted load machines are greatly reduced.

One more point worth mentioning is that there is a certain critical value of external resistance which will absorb the maximum amount of power from the system. This value corresponds to the ideal resistance for dynamic braking purposes on a synchronous motor, for which the critical value is approximately equal to 58 per cent of the transient reactance of the motor. As a grounding resistance, however, this particular value should be avoided since the opening of the prime mover throttle to supply the absorbed power may produce violent swings when the fault is cleared. Best results are usually obtained well above this critical point.

The correct value of neutral resistance to assure these advantages will generally provide adequate protection against dangerous oscillations from arcing grounds and will at the same time prevent doubling of surge voltages entering the machine whose neutral is grounded.

Most of the benefits accruing from the use of neutral resistors also apply if reactors are used. Moreover, there will be less I^2r loss in a reactor and its ohmic value may be somewhat lower for a given fault current since the inherent system impedances are themselves essentially reactive. For the same degree of current limitation, the dynamic voltage rise due to a ground fault will be less than with a resistor, but protection from unusual transient voltages is lacking. Reflections at the neutral of lightning and switching surges are possible, and for this reason in some cases a thyrite resistor has been used in parallel with the reactor.

When the neutral reactor is so designed as to give a line to ground short circuit current equal and opposite to the system charging current, it is called a Petersen coil. At the time of a ground, these currents must both flow through the fault, thus nearly cancelling each other. If the fault consists of an arcing ground caused by lightning or a momentary transient contact, the small resultant unity power factor current may not be enough to sustain the arc, which then simply goes out.

This device has been used extensively in Europe and Japan and has in recent years gained favor in the United States. However, there are a number of practical objections to the Petersen coil for steel mill service.

In the first place, to be effective the value of reactance must always be equal to the system capacity reactance. The constant switching of circuits in a steel mill would therefore require constant tap changing on the Petersen coil. Furthermore, the Petersen coil is useful only in cases of momentary or transient contacts of one line to ground, a condition seldom met with in a steel mill. It is worthless in cable systems or in connection with apparatus failure where the insulation is not self healing like air. Moreover, dangerous transient voltages have in some instances been observed during switching operations, so that it was found necessary to disconnect the Petersen coil when switching.

To avoid the possibility of these transient voltages, the Jonas dissonance coil was proposed, operating at ten to twenty-five per cent below the reactance of the Petersen coil. The bauch quench transformer is another modification, consisting of a star-delta connected transformer with a reactor in an open corner of the delta for tuning. Both of these devices are subject to the same general objections as the Petersen coil for steel mill service.

In cases where system neutral is not available, a grounding transformer may be provided. In its cheapest form it consists of a star connected zig-zag transformer having one-half the windings of each phase connected in opposition to one-half those of another phase, so that the zero sequence currents are limited only by the internal leakage reactance. The effect is the same as a neutral reactor of one-third the transformer reactance. Star-delta grounding transformers are also used even though they are more costly, because the secondary delta winding can be used for load purposes.

The kva. rating of the grounding transformer has an important bearing upon system performance since for a given per cent reactance, the value in ohms will vary inversely with the rating. In addition to the normal load current, if any, the transformer used for grounding should be capable of safely withstanding the expected ground fault current for the maximum possible duration of the fault.

Normally a ground fault will be cleared by relays within a fraction of a second. If for any reason the fault is not cleared automatically, the current will continue to flow and may result in damage both to the neutral impedance and to the machine whose neutral is grounded. The cost of a neutral resistor or reactor will be governed by the length of time it must carry the expected ground current.

In order to avoid the high cost of continuous duty equipment, it is good policy to protect the grounding apparatus by thermal or overcurrent relays which, after a short delay to permit line relays to operate, will sound an alarm indicating that a ground fault has not been properly cleared. To allow time for the operator to locate and clear the fault, a time rating of two minutes has become more or less standard for neutral grounding equipment.

For the purpose of providing flexibility in transferring the ground connection and for emergencies, a neutral circuit breaker is required. Its voltage rating should be that of the system and its rupture capacity that of a three phase breaker designed to interrupt the maximum ground fault current at rated line voltage.

TRANSFORMER SECONDARIES

While the foregoing discussion refers primarily to steel mills generating their own power, the same general principles apply to systems fed through transformers. Utilities appear to favor the grounding of each new step in the system involving transformation at the power source, as this assists in proper relaying by permitting the ground fault current to flow away from the power source in every case. The supply transformer secondaries would accordingly have their neutral grounded,

(*Please turn to page 53*)

The Use of the NORMAL CURVE in Problems of the STEEL INDUSTRY

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ASKANIA REGULATOR COMPANY
CHICAGO, ILLINOIS

▲ THE problems of the steel industry are somewhat unusual as compared with other manufacturing problems, insofar as an unusual number of variables enter even into the simplest process, making comparisons difficult. For instance, the variables entering a heat balance of an open hearth furnace are infinitely greater in number than those in a power plant in spite of the more complex nature of such a plant. The human element, the short life of the furnace, the widely varying materials to be worked with, the comparative lack of measuring instruments, make operation data on furnaces and on different operating methods on furnaces most questionable. The reason for this is that a greater number of variables affect each other in such a way that the ordinary algebraic averages only slightly vary in spite of comparatively greater variations of one variable.

Fortunately the statistical methods recently developed and lately applied to industrial problems offer a fair way of comparing results. The purpose of this discussion is to show the advantages of this method. The article does not pretend to go into the details, but tries to prove that the general fear of statistic is not at all justified, and that the fundamentals of statistical knowledge are an excellent tool for the engineer. More than a tool it is an instrument by means of which it is possible to visualize and to demonstrate operating data which are otherwise useless or of only little value.

To demonstrate the most important points, the examples will be simplified. The fundamental diagram for all statistical observations of the kind in which we are interested is the so called "normal curve" shown in Figure 1. It is a bell shaped curve that shows the distribution of variables over a certain range. The ordinate represents the number of tests, samples or percentage of the observed data and the abscissa usually the variable to be observed. The width of the curve designated by plus or minus 3*S*, 2*S* and 1*S* represents the deviation of the variable from the normal value line drawn vertically through the center of the bell shaped curve. Thus a minus value 2*S* or 3*S* shows the variations below the normal value and a plus value the variation above. In a later paragraph appears a detailed explana-

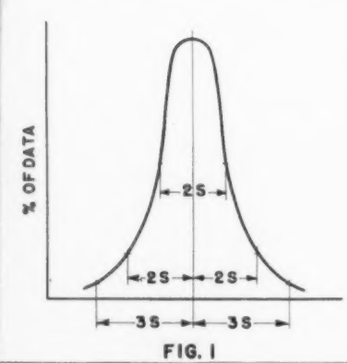

FIG. 1

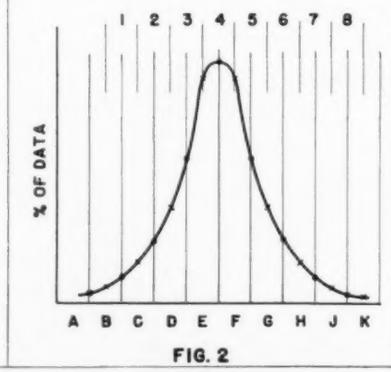

FIG. 2

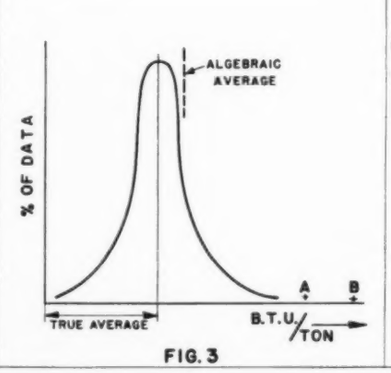

FIG. 3

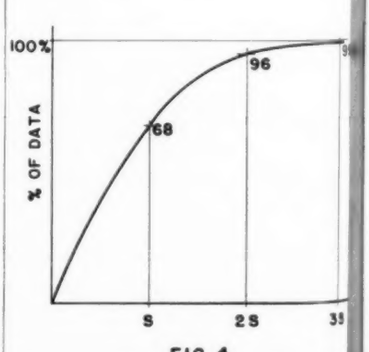

FIG. 4

tion of the relation between S and the range into which the number of test data fall. If the two branches of the curve were extended they would go theoretically to zero and infinity but for all practical purposes it is sufficient to consider only the range plus or minus $3S$ as this range covers 99.8 per cent of all data. If the width of the curve were limited to plus or minus $2S$, 95.5 per cent of all observed data would fall within its limits.

Tables are available that show the exact mathematical shape of this curve for a given value of S and a given maximum percentage. However, a few actual trials in plotting the curve will give the average engineer sufficient experience to interpolate the correct shape from the given data.

HOW TO PREPARE A CHART FROM GIVEN OBSERVATIONS

Assume that it is desired to check the Btu. per ton consumption of an open hearth furnace. First establish a number of equal ranges of the variable A to K. In other words for a given range of observed data plot the variable Btu. against the number of tests in per cent of total as ordinates which fall into each class. These would be represented by + in Figure 2. At times the figures might not be sufficient to permit the drawing of the complete curve. It is possible to increase the number of points on the curve by selecting a different group of ranges. These are plotted in Figure 2 and represented by the small circles. One hereby artificially "increases," so to speak, the number of data and hereby improves the accuracy of the curve.

ADVANTAGES OF THE METHOD

The curve establishes a definite average the value of which is not affected by extreme values. This is indicated in Figure 3 by the vertical line drawn through the center of the normal curve. The algebraic average is definitely affected by extreme values of A and B, and would naturally be greater or smaller than the true average since the shape of the curve is practically not affected by these extreme values.

The normal curve also shows the spread of the variations visually and indicates in its application to the problem possible guarantees to be allowed or tolerances to be granted in manufacture, insofar as it represents the number or percentage of acceptable or rejected parts falling within certain tolerances, and the effect of the tolerance on the number of acceptable parts. In analyzing the curve we find a definite relation between the value S and the number of data falling into a certain range.

For instance (see Figure 4) if the permissible variation is extended from $1S$ to $2S$, it means an increase of 28 per cent additional pieces that would be acceptable; while an increase from $2S$ to $3S$ would mean only an increase of 3.8 per cent. It therefore becomes a question of economy whether to choose a new process or machine to maintain a given standard with an additional investment or to consider the unusable pieces as waste.

Figure 5 illustrates two normal curves superimposed, one of which represents an expensive method of manufacture, and the other an inexpensive one. Note that the specification range definitely limits the quantity of acceptable units to a lower value in the inexpensive method. The graph will also show a tendency of the product to get into a state where a greater amount of rejections may be expected.

If the curve is being used to indicate the production of some machined product as shown in Figure 6, an indication of tool wear would immediately be shown. This is indicated by the tendency for the "normal curve" to wander to the right or left and at once warns the inspector that unless the cause for the change is stopped, the waste percentage will increase.

THE NORMAL CURVE IN THE STEEL INDUSTRY

A rather interesting application of this method was found in comparing Btu. per ton values on an open hearth after the installation of control equipment. The equipment was sold on a saving basis. The results obtained were contradicting, showing increases and decreases of the algebraic averages. As the plant was very thorough in the calculation of their Btu. distribution, an observation error was impossible. Showing the results of the test data on a frequency graph gave the

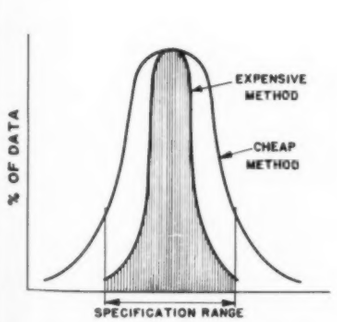

FIG. 5

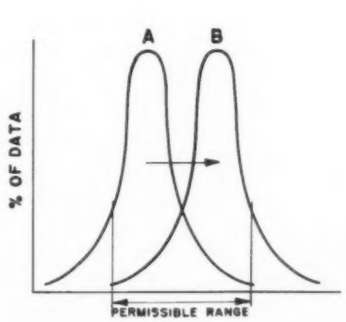

FIG. 6

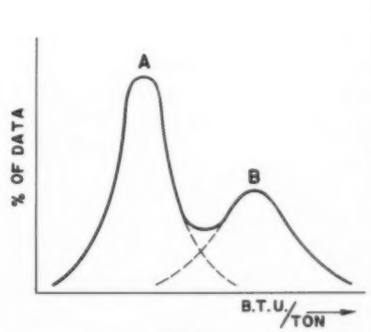

FIG. 7

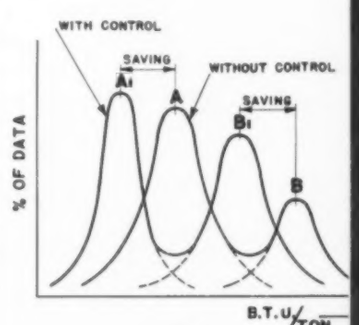

FIG. 8

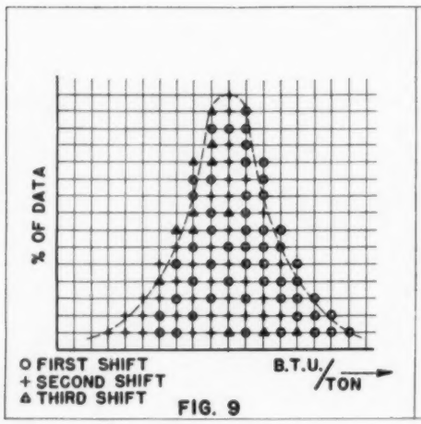

FIG. 9

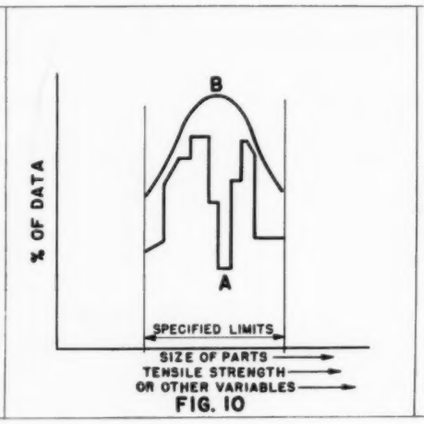

FIG. 10

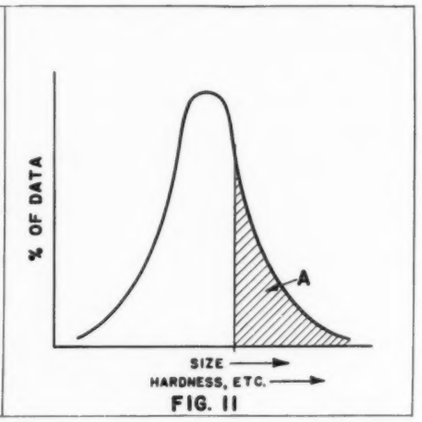

FIG. 11

interesting diagram as shown in Figure 7. The result showed definitely two superimposed normal curves *A* and *B*, indicating two distinct grades of steel affecting the Btu. per ton. As the two curves were overlapping each other, to a great extent, nobody realized the very definite difference between the two averages *A* and *B*, and as the ratio of steels *A* and *B* varied, the algebraic average varied also.

Since the process of production could not be interfered with, it was decided to superimpose the normal curves *A* and *B* without control and with control. (See Figure 8.) Thus the difference between the normal value line with control and the one without control represent the saving or loss. In this case the saving in fuel amounted to 10 per cent, and indicates forcefully how one may be misled by using algebraic averages when the true interpretation lies in using the normal curve.

STIMULATING COMPETITIVE SPIRIT IN THE PLANT

The normal curve may be used very effectively to stimulate the competitive spirit among employees. For example, in one steel plant where three shifts work on one open hearth furnace and where Btu. per ton figures are available, a board was prepared to indicate the results obtained by each shift. The operating data as obtained by each was plotted on this board. Distinctive buttons to represent each shift were inserted in the holes designating the respective range of Btu. per ton. The resultant curve is the "normal curve" as shown in Figure 9. Each shift was distinguished by marked buttons, the first using circles, the second crosses, and the third delta.

All things being equal the distribution to the right and left of the normal value line should be uniform. The distribution of the buttons shown in Figure 9 would indicate that the buttons on the left proved the operating skill of the shift which they represent or adverse operating conditions for the circle button gang which might require investigation.

VALUE AS TO PRODUCT CONTROL

Furthermore the normal curve may be of advantage to the manufacturer to show product uniformity. It is evident (see Figure 10) that fulfilling the same specifications, a product (*B*) indicating uniform manufacturing methods is preferable to a lot (*A*) which evidently is picked out of a number of various manufacturing lots. This leads some manufacturers to specify not only size limits but also to prescribe the "normal distribution" of the product.

If a branch of a normal curve is missing, the curve will not only show this fact, but also enable the investigator to estimate the number of parts taken out of the lot. For instance, the absence of *A* in Figure 11 would together with Figure 4 permit a very close estimate of the number of parts which had been removed.

The above examples are only a few outstanding points showing the possibilities of this method for the plant operator and for the management whom they should encourage to a deeper study of this valuable method.

One word at the end to dispel misgivings as to the possible limitation of the method to large quantities. It is admitted that very exact results are only obtainable with great numbers, but fortunately the accuracy increases only with the root value of the number of observations. The writer has found in his work that 40 observations on furnaces are satisfactory for comparisons. The greater the number of variables the more will the final curve approach the mathematical "normal" shape.

BOHO DISCUSSION

(*Continued from page 43*)

done in practice, or is there a reason for it, or was it simply shown on the diagram that way?

M. J. BOHO: It was simply shown on the diagram that way. Ordinarily, we try to get sufficient straight run ahead of the orifice, so that the placing of the butterfly will have little effect on the measurement. Also, in most cases, we are limited by the actual layout of the job as to where to put the orifice. As yet, the furnace manufacturers aren't giving us as much room for measuring orifices as we would like to have.

F. D. BURNE: The point I meant was that below the gas valve there is a varying pressure between the valve and the burner, and the orifice was in that line. Do you put it, preferably, where you have a variable pressure, or where you have a constant pressure?

M. J. BOHO: Usually, while the pressure is variable, it varies in small limits, and the total change in density, in so far as it affects the orifice, is rather small. There are other greater errors in the set-up that we can't do anything about, and smaller errors such as those due to density variations we just neglect.

G. R. MCDERMOTT: As I understand the author, when the ingots were brought up to rolling temperature it was found necessary to increase the ratio of air to gas in order to maintain the desired port velocity for proper flame distribution. This procedure is somewhat inconsistent when consideration is given to the fact that the modern pit is equipped with sand seals around the cover periphery in order to prevent, as much as possible, air infiltration with its attendant loss of combustion efficiency and increase in scale formation.

M. J. BOHO: Mr. Callinan's question as to the relative merits of regulation of the outlet damper from furnace pressure and from firing rate. In the first method, the outlet damper is positioned as necessary to maintain the pressure in the pit constant at some particular point; whereas, in the second method, the outlet damper is positioned according to firing rate as necessary to get the desired heating effect on all ingots without consideration of the pit pressure. With the second method of control, the pit pressure may, although not necessarily so, be constant. Up to date, both methods of stack damper control have not been placed in operation on similar pits under comparable conditions, and while each method has given excellent results, it is hardly fair to make any statement as to their relative merits. We hope soon to have both types of controls in operation on the same make of soaking pits in the same plant, at which time we will be in position to report on the relative efficiencies of the two methods of outlet damper control.

In connection with Mr. McDermott's observation regarding excess air at low firing rates when the steel ingots are up to temperature, we point out that this is a compromise. When a burner unit is developed which will adequately mix fuel and air so that combustion is complete at the very low firing rates encountered in the modern insulated soaking pit and, at the same time, give sufficient velocity and direction at low firing rates, without excessive localized heating at some point at higher rates, it may very well be that the increase in excess air may be unnecessary. Some sort of collapsible burner, however, would probably be required when it is considered that, in the ordinary burner, gas and air pressures will vary almost 100 to 1 on a turndown of 10 to 1.

While the idea of adding excess air at the low firing rates encountered when the steel ingots are up to temperature may sound undesirable because of scaling, it is well to remember that the surface scale, unless it is accidentally washed or knocked off, is already formed on the ingot at the time the steel is up to temperature and the firing rate reduced. This porous scale acts as an insulator or jacket preventing further action by the excess air on the hot steel underneath. Fortunately, combustion efficiency does not suffer too much since, at this time, the rate of gas flow is lowest and the loss due to excess air smallest.

NEUTRAL GROUNDING *in* A-C. SYSTEMS *for* STEEL MILLS

(*Continued from page 49*)

assuming of course, the transformers also have a delta connected winding.

Inasmuch as steel mills differ somewhat in their low voltage requirements, secondary distribution systems vary all the way from a simple radial feeder system to complicated networks fed through thousands of kva. of transformer capacity. While overvoltages from arcing grounds are not likely, the advantages of grounding from the standpoint of protection are appreciable. The reduction of hazard to life is perhaps more apparent on 110 and 220 volt systems than on 440 volts, although available information does not appear to be conclusive.

CONCLUSIONS

When a steel mill distribution system acquires such proportions that repeated evidence of over-voltages is encountered, some form of neutral grounding may wel be considered. In order to arrive at a decision it may be helpful to keep accurate records of system faults, particularly of those occurring at about the same time. The percentage of these simultaneous faults plotted over a period of time will when given a direct indication of the extent to which neutral grounding will reduce unnecessary failures and improve service continuity.

Of the various methods of neutral grounding in common use, the resistor ground seems most suitable for steel mill service. A neutral resistor sufficient to limit the ground fault current to a moderate value has many advantages over most other types of grounding. The neutral reactor is in some respects even more desirable, but does not afford protection against surges and transients unless supplemented by a parallel resistor.

W. H. BURR

DEVELOPMENTS *in* *The Iron and Steel Industry* DURING *1940*

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▲ AS the year 1940 draws to a close, the steel industry is operating at a rate beyond any previous experience. The combination of export, domestic, and defense requirements is at present taxing the capacity of the industry which has often been termed over-expanded. Rated ingot capacity, according to American Iron and Steel Institute figures, is 81,829,000 net tons. Previous highest annual production was 60,829,752 tons, while the average for the past ten years was 36,906,682 tons per year. However, many open hearth plants are bordering on obsolescence, only 27 furnaces having been built in the past eight years. In spite of this, many steel company executives have held that present producing capacity, operating at an average rate of between 80 and 90 per cent, is sufficient for both normal and armament needs, although expansion of armor plate, forging, shipbuilding, etc., are necessary. It was further believed that any shortage in primary production will be felt first in blast furnace capacity.

An opposite stand has been taken in certain quarters, culminating in a report released by the National Resources Planning Board which indicates that more than a billion dollars should be spent for new capacity for a national consumer income of 94 billion dollars.

Whether this question has been settled or not, a number of expansion programs have been announced by various companies, including coking, blast furnace, open hearth, electric furnace and mill facilities.

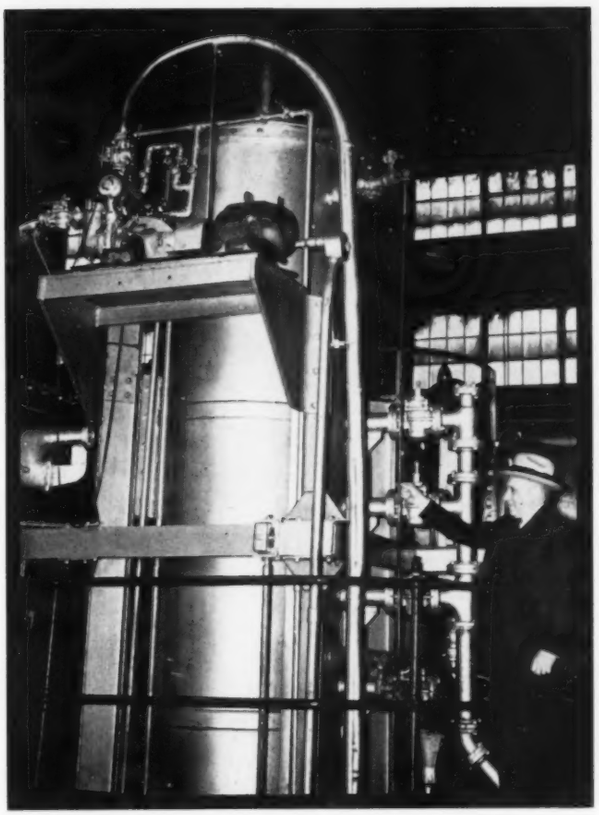
The total amount of money budgeted at the start of 1940 by steel companies for plant modernization was reported as $146,000,000. This estimate represented an increase of about 20 per cent over the previous year, and has been considerably exceeded by the year's actual expenditures, due to the tremendous increase in production requirements.

Most steel plant construction projects under way during 1940 were in the nature of rehabilitation of existing primary production facilities, with installation of some new finishing mills and processing lines to round out overall production capacity. The National Defense Program has necessitated the installation of considerable new equipment, particularly electric furnaces for the quantity production of high grade carbon and alloy steels, furnaces for heat treatment of armor and ordnance, and large forging presses.

COKE OVEN AND BLAST FURNACES

As the year closes, it is evident that the current rate of operations has brought out a shortage in coking capacity. This has brought about the use of a considerable number of old bee-hive units, and the starting of additional long-idle bee-hive units is under consideration. This regrettable waste of valuable by-products is to some extent a consequence of the depression years, when many producers allowed by-product coking batteries to go to ruin, deeming that there would be no call for the "excess" capacity. Recent press releases show a number (about 8) of new battery installations and additions, totaling more than 4,000,000 tons per year capacity, while many old batteries have been repaired.

The growing demand for pyridine in the chemical and medical fields has turned the attention of by-product coke plant operators to the recovery of the tar bases present in coke oven gas. Batch processes for the recovery have been in use for over twenty years, but the continuous process, developed in 1939, offers more complete recovery. A number of these plants are now in operation. A small quantity of saturator solution (4 or 5 gal. per min.) is withdrawn from the lye pot connected with the saturator, stripped of its pyridine content, and continuously returned to the saturator. Pyridine content of the saturator bath can be maintained at about 1 per cent, improving sulphate quality, and losses are reduced to a minimum. The crude product made generally contains 50–60 per cent bases and 12–15 per cent water.



The development of a continuous, efficient method of pyridine recovery has increased yield, while improving quality of ammonium sulphate.

Figures released by the American Iron and Steel Institute on the country's blast furnace capacity show a reduction during the year of 1939. At the start of 1940, the nation's blast furnaces showed a rated capacity of 55,723,640 net tons, which is about 600,000 tons less than the preceding year. This capacity has slowly but steadily declined since 1930, a fact which may be attributed to increased use of steel scrap in steel-making processes. This trend may be reversed by the activity throughout the year in the rehabilitation of blast furnaces. In all parts of the country, producers have rebuilt stacks, usually to considerably enlarged dimensions. A pronounced tendency is apparent towards increased furnace height, several furnaces using a height of about 105 ft., with good results. Many of the modernized stacks have been designed for a rating of 1000 tons of iron per day, with hearth diameters of 25–27 ft. In some cases, however, smaller capacities were desired, and furnace lines were accordingly held to lower values. One example of this is in the Chicago district, where an old furnace was rebuilt with a 20 ft. hearth and a height of 94 ft. from iron notch to hopper ring. This stack offers an effective working volume above the tuyeres of about 25,000 cu. ft.

In the Pittsburgh area, one modernization job presented an interesting problem, in that most of the shell and mantle was replaced without disturbing the top structure, skip incline, or downcomers. The wider use of welding as a means of fabricating blast furnace shells, as well as stoves and auxiliary equipment, is worthy of note.

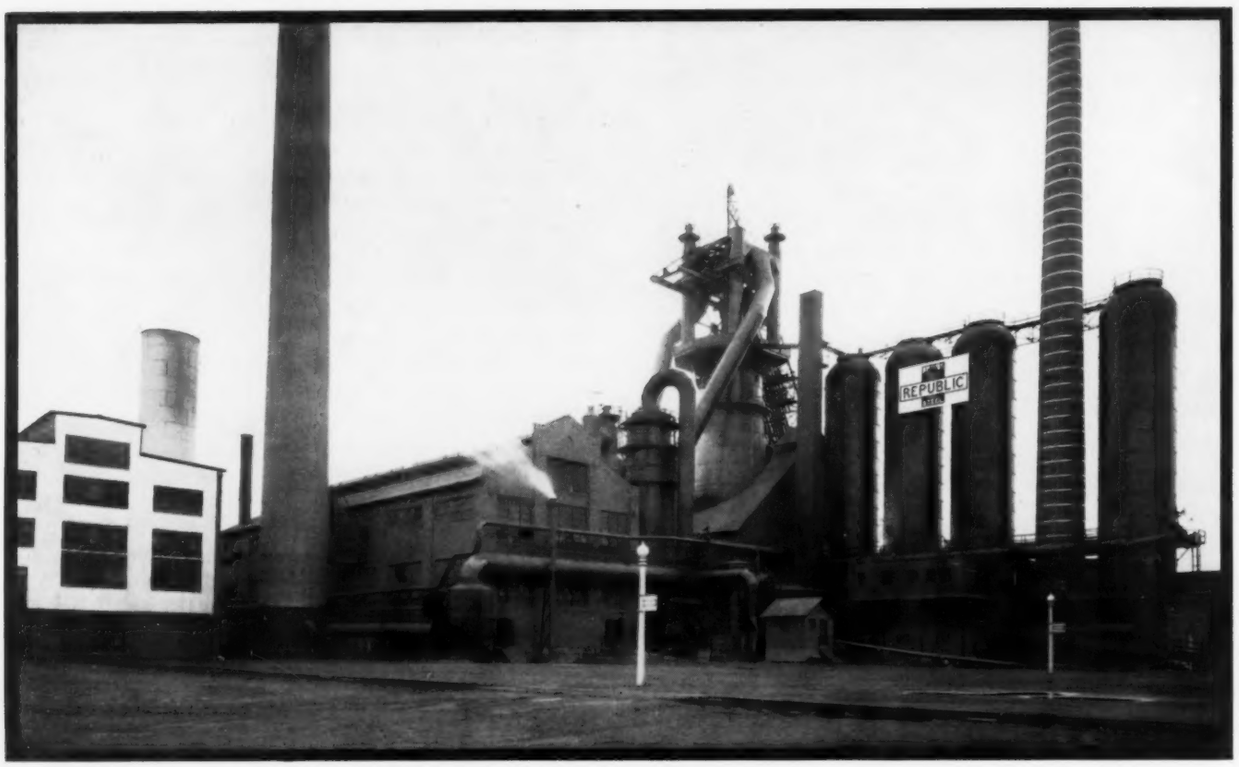
The life of furnace linings has been gradually extended, due to improved refractory quality, smoother furnace operation, and furnace enlargement. Productions of over 2,000,000 tons of iron on a lining are not uncommon, and one report shows a total life of almost 3,000,000 tons.

A development which may extend furnace life much further is the use of carbon bricks and blocks as lining material. It is reported that 75 per cent of all German blast furnaces are now carbon lined, and there is an awakening interest in the United States. In the standard brick sizes, the use of carbon is merely a substitution. It is felt, however, that large blocks are preferable, with the hearth built up either of large rectangular blocks or of circular blocks about a truncated cone section. In either case, joints are staggered, and the blocks are accurately machined to size. No cooling plates are required with the carbon lining, making for cheaper and simpler construction. Since neither metal nor slag attacks carbon, the hearth does not cut out at all, and no salamanders are formed with a well built hearth. The complete economic picture can be determined only by trial, and it is understood that there is some experimentation now under way.

Stock distribution continues to receive the attention it deserves. Careful grading and sizing of the materials bring about improved distribution, and, consequently, improved gas-solid contact in the stock column. Continued interest in material preparation and in the use of the more undesirable grades of material is to be noted in the adoption of blending of ores by bedding, the sintering of carbonate ores, further exploitation of New York magnetites, and the installation of ore concentration plants in the southern districts. One producer is proceeding with large scale experimentation on a process of concentration of the highly siliceous ores from the vicinity of Grace's Gap and northward on Red Mountain, in Alabama.

A new and simplified type of revolving distributor has been developed, and several installations are now in service. In this control the angle of rotation of the distributor is not changed after a fixed number or group of skip or small bell discharges. The angle of rotation is changed in response to and in step with the discharges of the large bell. Thus all the skip loads placed on the large bell for one discharge have a given rotation. The next group of skip loads placed on the large bell for its next discharge have another rotation. Extra loads placed on the large bell have the same rotation as the regular loads in a group placed on that bell. This distributor control affords a definitely regular or symmetrical distribution, and enjoys advantages of simplicity in view of the fact that an independent mechanism for counting the skip discharges is not required.

The majority of modernization programs have included improved charging control. Recent trends are toward better screening of coke before entering the skip buckets, through the use of mechanical shaker screens. Weigh hoppers, automatically controlled and interlocked with the skip control, are used, so that the coke is handled from bin to furnace at definite, selected points



A considerable number of blast furnaces have been rebuilt, usually to considerably enlarged dimensions and capacity.

in the round without attention from the scale car operator.

Special problems have arisen in connection with many of these installations, and a number of improvements and variations consequently have been developed.

In the past, charging controls have been associated mainly with conventional electrically-operated two-skip installations. During the past year three charging controls have been placed in service in connection with steam-operated skips. A control is now being built for use at a furnace having a single electrically-driven skip. Likewise, control systems have been applied in connection with pneumatically-operated, steam-operated, oil-operated, or electrically-operated bells.

Gravity-opened bells, operated by pneumatic bell hoists, which in turn are controlled by motor-operated valves, have now achieved almost universal acceptance. A number of mechanical refinements in design have been applied to these hoists. An improved slack cable device has been developed which prevents the large bell hoist from paying out an appreciable amount of slack cable if the bell should be held up by gas pressure. A method has been devised to absorb and dissipate the energy released by an explosion between bells. The valving is arranged to permit independent control of the speed and time of opening, pause and closing the large bell. A very fast opening speed is now possible. Some operators value this characteristic because of its influence on distribution of the stock.

The first installation of a new stock water metering device is now being made. This comprises essentially a tank from which selectively measured quantities of water may be discharged. Inlet and discharge valves are motor-operated. The scale car operator merely pushes a button to initiate a cycle of operations which involves the discharge of the measured quantity of water into whichever skip is in the pit, and the refilling of the tank. The quantity of water to be discharged may be varied by moving a small dial switch. In connection with a charging control, the water charging operation may be made automatic. In such event, pre-determined quantities of water will be automatically delivered into selected skips without attention on the part of the scale car operator.

Many blast furnace plants are at present examining their gas cleaning equipment in order to determine whether more efficient cleaning of gas will be economically beneficial. The use of smaller checker openings in stoves requires a cleaner gas, two inch checkers requiring a cleanliness of about .01 grains of dust per cu. ft. This degree of cleaning is usually obtained with electrical precipitators, wet disintegrators having gradually been replaced by this newer method. Primary wet washers have been reduced considerably in size, yet through improved design, are able to clean the gas from a large furnace down to less than .2 grains per cu. ft.

The availability of clean gas has permitted a reduction in size of hot blast stove checkerwork. The smaller checker openings, which are found down to 1½ in., afford more efficient blast heating, and the use of higher blast temperatures is increasing. Various reports show hot blast temperatures up to 1600 degrees F., and it has

been found practical to obtain these high temperatures with only three stoves of modern design, in place of the four previously used.

Hot blast temperatures are closely controlled by control systems consisting of a thermocouple projecting into the hot blast main in front of the bustle pipe, a recorder-controller, a delay detector, a motor-operated valve drive unit, a remote control station, and a control panel. Through proportional control, very small temperature changes are detected and headed off without hunting.

Interest in the air-conditioning of the blast is reflected in the development of a new process, wherein moisture is absorbed from atmospheric air with a hygroscopic solution. Air to the blowers is thus controlled at from one to three grains per cu. ft. as desired. In addition to providing constant low moisture, the system delivers air at constant temperature. Thus, constant weight of air is automatically delivered, and it is stated that the low costs of investment, operating, and maintenance bring dry blast within a practical economic range. The results of this installation, as well as those of the spray type dehumidifier reported at a southern plant a year ago, are under careful consideration by all blast furnace operators. Announcement of installation plans for a spray type unit has been recently made by a company in the Pittsburgh district.

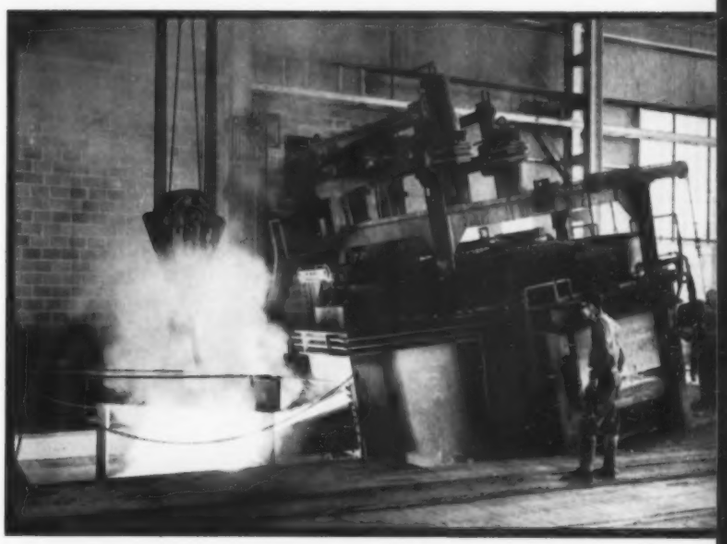
The Bureau of Mines has reported additional data on the desulphurization of pig iron with calcium carbide. This process depends on the reaction between solid calcium carbide, preferably finer than 48 mesh screen, and liquid iron. Good dispersion of the carbide is essential, and a mechanical unit for adding the finely ground carbide to large quantities of molten iron has been developed. An important difference between desulphurization with calcium carbide and with the alkalies is the materially reduced degree of reversion of sulphur to the iron in the former process if the desulphurized metal is not immediately skimmed.

STEEL MAKING

The demand for large tonnages of high grade carbon and alloy steels for armor plate and ordnance, as well as for automotive, aviation, machine tool, and other industries, has caused great expansion in electric arc furnaces. It is estimated that the new additions will add about 450,000 tons to the annual electric furnace capacity, which at the first of this year was estimated to be 1,592,080 net tons.

One producer has added several 50 ton units, each provided with 12,000 kva. transformer capacity. The transformers have motor-operated tap changers mounted on the transformer case, but in a separate oil-filled compartment. Full capacity is available with delta connections at secondary voltages of 275, 260, 245, 230, and 215; 200 and 185 volts are available with delta connections and reduced capacity, and 159 and 107 volts with Y-connections. The transformers are oil-immersed, water-cooled, and operate on a primary voltage of 22,000.

Many other companies have also installed additional electric arc furnace capacity, all of which carry greater transformer capacity than was formerly the practice.



New electric furnaces added and in progress will bring national capacity above 2,000,000 net tons per year.

Perhaps the highest relative transformer capacity is used on two 25-ton furnaces recently installed, each of which is serviced by a 12,000 kva. transformer with 10 secondary voltages. These furnaces are claimed to be the largest using top charging.

Investigations of arc furnace operation by means of the klydonograph have shown surge voltages high enough to endanger the transformer windings and circuit breaker and switchgear equipment. Adequate protection may be afforded by additional insulation of the transformer windings and switchgear equipment, and by the installation of surge capacitors to absorb the high surge voltages.

The awakened interest which has been evident for some time in the bessemer process leads some sources to believe that steel production by this method is much too low for a correct balance of processes within the steel industry. The use of the photo-cell, amplifier arrangement, and recorder for registering the bessemer blow has been more widely adopted, and efforts are now directed toward determination of the exact length of after-blow most favorable for each grade of product. It is felt that the uniformity of bessemer steel which is possible through this and other types of control, together with present economic considerations, may tend to increase production by this process either direct or through duplexing. Various methods for desulphurization and dephosphorization are in use.

One method of dephosphorization of bessemer steel in use at present requires a blown metal temperature above normal so as to melt the dephosphorizing agent which is added in the cold state. As temperature affects slag fluidity, a silicon-manganese ratio of 2, coupled with young blowing, is necessary to produce the proper type of thick slag. Silicon content of the iron must be carried about .25 per cent above normal bessemer practice. Scrap additions are reduced in order to hold temperature up. The vessel is turned down from one to

six seconds after the first change appears, depending on the silicon content. Slag is skimmed from the metal as the latter is poured into the ladle, and the dephosphorizer is added to the stream of metal. The mixture consists of 50 per cent impure lime, 30 per cent dried roll scale, and 20 per cent dried flux, which, when melted forms a slag with a chemical analysis of 48 per cent CaO, 28 per cent Fe_2O_3, 7 per cent SiO_2, and 7 per cent Al_2O_3. The operation is completed in about 30 seconds and phosphorus is reduced from .095–.100 per cent down to .020–.040 per cent. If the material is added in the molten state, phosphorus is reduced only to .040–.050 per cent. Steel produced by this method has a combination of properties superior to those of steels made in the usual way, and it is applicable to a much broader range of products.

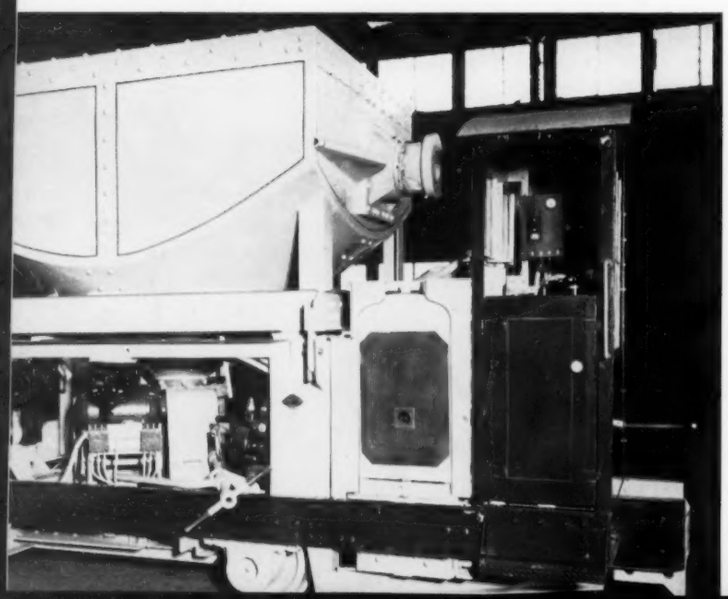
The Perrin process, in which steel and slag are separately melted and brought together in the ladle, also deoxidizes and dephosphorizes very rapidly, due to a high degree of surface contact between slag and metal. Much experimental work has been done on various applications of this process.

Activity in open hearth departments progressed largely along the lines of improvement of various items of furnaces and auxiliaries. No new capacity was added during the year, but the never-ending search for better and more economical methods of furnace construction, operation, tapping and pouring continued.

Improved construction of the full sloping back wall allows the thickness of the middle and upper portions of the wall, as maintained in service, to be materially increased relative to the thickness of the lower portion. This change in design, which is accomplished with the customary amount of total outward slope, reduces heat loss and maintenance cost, and has been installed on a number of furnaces.

The possibilities of the all-basic open hearth furnace is of considerable interest, due to the possibility of raising furnace temperature, increasing output, reducing lost time, and lowering slag volume, and results obtained with this type of construction have gradually improved. The first installations were relatively short lived, but recently furnace life has lengthened considerably. This is due in part to the development of volume-stable chrome-magnesite bricks of high thermal shock resistance and high refractoriness under load. Such bricks still show bursting, due to solid solution of iron oxide in the chrome ore, but if adequate attention is given to details of design, such as springing and suspension of the roof, all-basic furnaces may operate for long periods.

This dolomite machine is equipped with diesel-electric generator set, making it independent of other power supply.



Improved designs are evident in the various auxiliary equipment of the open hearth department. One manufacturer has announced an improved dolomite throwing machine for making up open hearth banks. An advantage of the improved machine is that it operates under its own power. A generator, driven by either a diesel or gasoline engine, develops electric power for the motor operating the dolomite throwing mechanism, and also for the motor which propels the machine along the rails. Thus, the machine transports dolomite from the storage as well as throwing it on the furnace banks, all without the necessity of crane service.

All-welded open hearth ladles, mentioned last year, have grown in favor as well as in size. One company is now using welded ladles of 190 tons capacity. These are of eliptical design, 15 ft. 6⅜ in. and 12 ft. 2 in. in diameter at the top, 12 ft. 4⅜₁₆ in. and 9 ft. 4⅜₁₆ in. in diameter at the bottom, and 12 ft. 9½ in. overall depth. The shell plate is 1⅛ in. thick, and is made in two halves, butt-welded together with a vertical double-V weld.

The most recent development in open hearth bath temperature measurement consists of a metal tube which is inserted in the bath, and through which a current of low pressure air is passed. A high speed radiation pipe couple and recorder completes the apparatus, and results have been promising although all equipment of this sort seems subject to a varying degree of accuracy and deterioration under service.

Increased use of rapid methods for carbon determination is to be noted. The latest method to be advanced is based on the relation which exists between carbon content and magnetic permeability, and is relatively inexpensive, rugged, and accurate. The apparatus for making the determination consists of a special form of permeameter which measures the changing flux in the sample bar produced by a known change in magnetizing force. In this case, the change in magnetizing force is produced by reversing the current in the magnetizing coil. Deflections of a galvanometer for reversal of a given magnetizing current are calibrated in terms of carbon content. Equipment of this type has been in use in various plants for some time, and it has been stated that the effect of nickel and molybdenum must be taken into consideration, and that the various factors involved in taking the sample must be carefully standardized, if consistently accurate results are to be obtained.

Because of the possibility of world conditions interrupting our manganese supply, considerable quantities have been stocked in this country, while imports continue at a high level. Plans are also under way for supplementing imports through domestic production of suitable ores. Commercial production of electrolytic manganese, 99.9 per cent pure, is now established, and although the price is high, increased production and

refinements in the process should reduce the price materially.

Competition throughout industry in general has resulted in a trend toward cheaper materials which may give the same properties and service as more expensive materials. This is particularly noticeable in the increasing use, by the steel consuming industries, of carbon steels in place of the more expensive alloy steels. To make this substitution and still maintain the same properties and degree of service, it is necessary that the carbon steels be greatly improved over their characteristics of a few years ago. Furthermore, mass production demands a high degree of uniformity of material. In order to meet the steadily increasing demands of users for steels of improved uniform physical properties, steel producers found it imperative to maintain closer control of chemical analyses, and to develop new methods of control and production to meet requirements as to cleanliness, grain size, hardenability, uniformity, and surface quality. Most of these properties have been fixed by the time the steel is in the molds, and it has therefore been necessary to develop much closer control of open hearth practice. The proportions, composition, and physical characteristics of the charge, furnace design, fuel, combustion conditions, temperatures, slag composition and properties, furnace additions, furnace and ladle deoxidation, teeming conditions, and mold design and conditioning all affect steel quality. Various methods of control of these items have been used for years. Existing control methods have been improved, and new ones are in the process of development.

Of the foregoing, slag properties and deoxidation practice are major factors influencing steel quality. Reports of one series of investigations make the following recommendations: (1) Charge a slight deficiency of lime and make additions of burnt lime as necessary to maintain a basicity range of 2.2–2.5 V-value during the refining period. (2) Maintain a fluid slag (viscosity of 2 to 4 in. as measured by the Herty viscosimeter) within the above basicity range during the refining period by the use of fluorspar. (3) Charge heats to melt somewhat above the desired melt carbon, and use hard ore as required to reduce the carbon rapidly. No ore to be added to quality heats during the last 2 hr. before tap. (4) Thicken up the slag by additions of burnt lime just prior to charging furnace deoxidizers, in order to decrease the rate of transfer of FeO to the bath.

The use of magnaflux testing on certain classes of products has led to a tightening up against inclusions in the steel. Great stress is also laid on machineability, and on the development of very high strength products.

During the past year, over 4,500,000 tons of rimming steel were produced in twenty-nine steel works, using a patented sodium fluoride treatment which promotes the rimming action, tending to eliminate thin-skinned ingots. This process has been recently supplemented by subsequent use of a deoxidizing agent in the top of the ingot to stop the rimming action, thereby reducing segregation in the central and top portion of the ingot, with decreased top discard and increased yield.

A new steel making process, termed pluramelt, was announced during the year, by means of which clad material is produced. The composite material is made with both component analyses at least in part molten at the same time, in order to secure absolute metallic continuity. In its numerous analyses, the composite material is the product of an electric furnace melting technique, as a result of which all of the special composition materials and a small part of the cheaper material are melted and joined during this operation. The furnace is radically different from the conventional type of electric furnace, in that the functions of steel making and of the mold are combined. Thus, single ingots of two or more compositions, integrally bonded together, may be produced and subsequently reduced to plates, sheets, or wire.

Carbon and graphite products are being adopted for many new uses in the iron and steel industry because of their physical and chemical properties. These products are highly resistant to the action of most corrosive agents, have good mechanical strength and resistance to thermal shock, and are infusible. Graphite products have excellent heat transfer properties, while carbon is used where low heat transfer is required. Both products may be made impervious to resist seepage. Graphite powder is used for mold wash, and carbon powder with hot tops to reduce piping. Carbon, in suitable shapes, has proven excellent for mold plugs, stopper heads, packing material for gas scrubbing towers, and as lining for desulphurizing ladles, pickling tanks, and furnaces. Carbon and graphite pipe, valves, and fittings are used in any construction where corrosion resistance is needed, and graphite molds and crucibles find numerous applications.

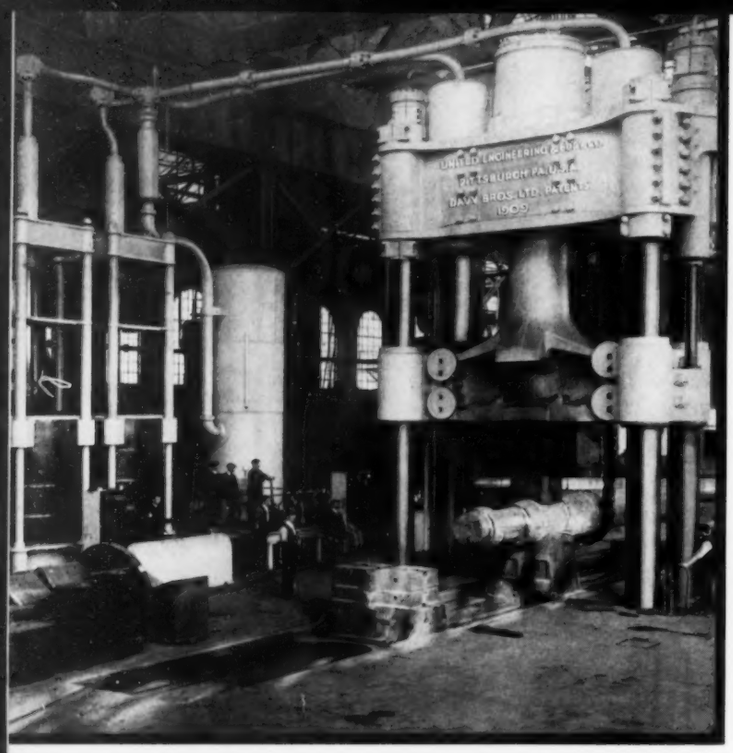
Published results of experiments dealing with the relation of ingot surface and sub-surface defects, such as blow holes, cracks, etc., to defects found on the direct rolled product, show that all surface defects, other than mill defects, on direct rolled product have their origin on or in the ingot. Direct rolled product surface follows directly with mold wall surface or pouring life, other factors being equal. Properly tarred molds apparently produce a definite improvement in bloom surface, although the benefit decreases as mold life lengthens. At some age (55–65 heats) fire-checked surface of mold walls may become troublesome.

Better care of ingot molds and more attention to pit and pouring practices has brought fine returns. Maintaining close control of temperature, pouring speed, and mold condition is valuable in keeping cost down and quality up.

FORGING AND ROLLING

The production of armor plate, recognized as a bottleneck in the national defense plan, has received considerable attention. Difficulties in casting and handling the ingots, which run up to 250 tons in weight, limit production of the heaviest plates to three companies, but plans for expansion in this field, as well as in the lighter classes, are under way. Several large presses for this type of work are under construction or rehabilitation. The smaller presses for shell piercing and forming have also been developed to a new high in efficiency and productivity.

A new hydraulic shell forging press has been announced, designed upon the principle of making a complete shell forging in one operation without extrusion of the steel during piercing of the billet. The process thus eliminates a second operation, gives great accuracy, and requires a minimum amount of metal in



New installations and rehabilitation of forging presses have received marked impetus from national defense activity.

the blank. The heated blank is inserted vertically in a split, hinged die. A control lever sets in motion two hydraulic horizontal rams that operate wedges for closing the water-cooled die around the blank, and at the same time causes a lower verticle supporting ram to move upward. Actuated by the top, main hydraulic ram, the punch unit moves downward into the blank for the piercing operation. As the punch progresses into the blank, the metal flows sideways and downward beside and ahead of the punch tip. When the punch reaches the bottom of its stroke, a lever is automatically tripped for the return stroke, and when the punch has been withdrawn, the die is opened. The press is designed to forge shells of 75–155 mm., and requires only about two seconds for the actual piercing operation.

Another method of shell forging uses a piercing press consisting of two revolving turrets. One turret, revolving in a horizontal plane, carries six dies into which the heated blanks are placed. The second turret, which revolves in a vertical plane, carries six punches. After piercing in this equipment, the blanks are entered into a tube mill of the Assel type, where they are finished ready for machining.

All of the new methods developed point to reduced size of the blanks, thus saving material and reducing machine work.

A forging hammer of new design has been brought out, in nine sizes, with falling weights of 200–3000 lb. Due to heavy anvil construction (never less than 15 times the falling weight), and to high impact speeds, more actual forging per blow is claimed. The ram cylinder operates from compressed air provided by a compression piston in a separate cylinder driven by a crank through a speed reducer from an electric motor.

One of the most recent developments in handling and manipulating of forgings under the steam hammer and press is a floor manipulator which travels about as an independent unit under its own power and can work freely at any point around furnace, press or hammer. This machine is built in two sizes, one handling loads up to 2000 lb. while the large size handles a maximum load of 6000 lb. All motions, except floor travel, are hydraulic, including tilting or raising of the peel, opening and closing of the tong shoes, rotation of tong head, and steering. These motions are actuated by a motor-driven oil pump. The tractor motion is actuated by another electric motor. Power for both motors is received from a flexible cable attached to a rotating collector mounted at the top of the collector mast. This unit offers excellent mobility, unrestricted working area, and ease of operation.

Blooming and bar mill activity has been confined largely to the improvement and overhauling of existing equipment, some of which has stood idle for about ten years. Some plate mills have installed new furnaces and auxiliaries, giving increased mill capacity.

For the first year in the last six, no new wide strip mills went into operation. The total number of mills of this type, 36 in. or more in width, now stands at 28, with a nominal capacity of 17,616,368 net tons per year. Actually, these mills might well be rated at more than 22,000,000 net tons per year, as they are fully capable of rolling this amount of steel. It is interesting to note that these mills are well adapted for rolling light armor plate, many already having produced one inch plate, and the majority being able to make similar products with some changes.

Two of the early strip mills, built in 1926 and 1928 respectively, were increased in width and in rolling speed, bringing them more in line with the later mills. These changes involved the use of bigger motors, increased converting equipment, modernization of switchgear, and improvements in auxiliaries. On one of these mills, two 3500 kw. mercury arc rectifiers will be used to supplement the three 3000 kw. motor-generators already installed. This is the first American use of rectifiers for main roll drives, and will be watched with interest by the industry. The runout tables and strip coilers of both of these mills were rebuilt, using d-c. mill type motors with variable voltage control. It has also been announced that the pioneer continuous sheet mill at Ashland, Kentucky, will be partially rebuilt and widened.

Improvements have been made in the control of flying shears used on continuous hot strip mills. Heretofore, these shears were connected to the last mill stand, either through an adjustable ratio gear unit or through a hydraulic transmission, in order to maintain the necessary accuracy of the cut. The new control provides a purely electrical tie between the mill and the shear, eliminating the mechanical tie altogether, yet maintaining as good or better accuracy of the cut. Electronic regulator and an amplidyne exciter have been successfully employed.

A recently announced width gauge, developed primarily for use on hot strip mills, measures the width of rapidly moving strip with an accuracy of $\frac{1}{8}$ in. The strip passes between two light beams which follow the edges as the strip widens, narrows, or shifts. This is effected by projecting a narrow beam of light upon a galvanometer-mounted mirror, which reflects the beam

to a photo-tube below the strip. The electric circuit is arranged so that the photo-tube controls input to the galvanometer, causing the mirror to move so that the beam of light is always partially interrupted by the edge of the strip. Two units are used, one on each side of the strip, so arranged that, if the beams must move apart or toward each other, the amount of over-width or under-width is indicated on an instrument. This development is also applicable to cold mills.

A new type of spray nozzle for either water or oil for both low and high pressure service has been developed. This new design, which has received exhaustive service tests, consists of only two parts, a stainless steel header adapter and a nozzle designed to give maximum impinging force over a wide area. The nozzle, which is available in several sizes, produces an even spray with no feather edges.

Notable improvements have been made in the rotating machines and variable voltage control equipment for cold strip mills to enable faster acceleration and higher rolling speeds, with resultant increased output and higher percentage of on-gauge strip.

Fast acceleration without exceeding reasonable limits of accelerating torques requires low WR^2 of the mill and reel motors. In some cases the desired low WR^2 can be obtained by special design to make the motor armature of small diameter and long core, and in a few cases it has been necessary to resort to double armature construction. Mill speeds frequently are high enough to permit direct connection of the motors to some of the mill stands, and the lower motor speeds and elimination of the reduction gear set result in lower WR^2, referred to the mill shaft, than is possible with geared drives.

To avoid looping or stretching the strip between stands it is essential that the speed relations between the several tandem stands be maintained the same at the low threading speed, and during acceleration and deceleration, as at the normal rolling speed, and there has been developed a system of control comprising a series booster generator in the armature circuit of each mill motor, and an auxiliary exciter driven by each mill motor, to automatically compensate for the varying effects of motor IR drop and armature demagnetization, and thus cause the motor speeds to change in almost exact proportion to the bus voltage, independently of the motor load or shunt field setting, and hence maintain the same speed relations throughout the threading, accelerating, running, and decelerating cycle. This system of control has been applied to three new high-speed tandem mills put into service during the year, and equipment for additional mills is being built.

The drive for a four-stand tandem cold reduction strip mill, put into operation early this year for the production of thin strip for tinplate, consists of a 700 hp., 350/857 rpm. motor geared to stand No. 1, a 1750 hp., 300/600 rpm. motor geared to stand No. 2, a 1750 hp., 175/350 rpm. motor direct connected to stand No. 3, a 2500 hp., 250/500 rpm. motor direct connected to stand No. 4, and a 300 hp., 125/600 rpm. motor direct connected to the winding reel. The motors for stand No. 4 and the winding reel are of double armature construction. Power for the mill and reel motors is furnished by a 6000 kw. motor generator set consisting of two 3000 kw., 720 volt, direct current generators and 8400 hp., 6600 volt, 60 cycle, 360 rpm. synchronous motor. The mill normally operates at strip delivery speeds between 2000 and 2500 ft. per min., normal accelerating time is less than 8 seconds, and maximum output of 32 gauge tinplate strip has reached nearly 500 net tons in an 8-hour turn.

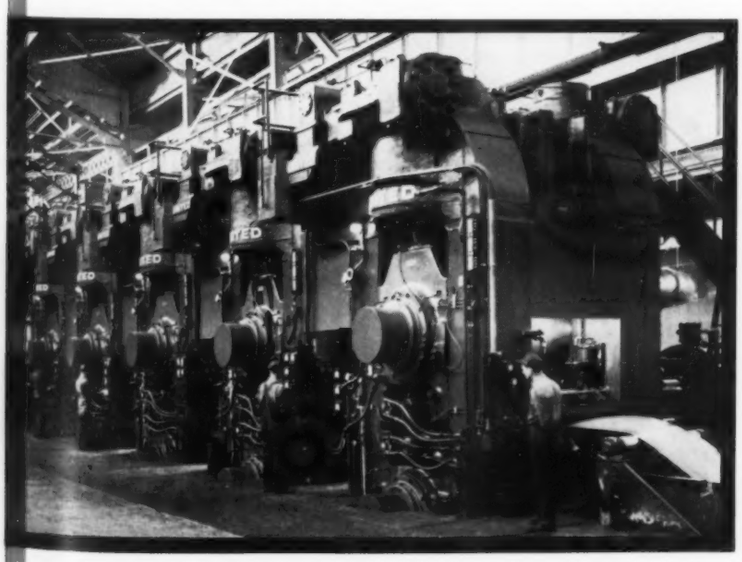
There has also been put into service a 55 in. wide four-stand tandem cold reduction strip mill, to produce intermediate and heavy gauge strip for enamelling and galvanizing stock, automobile sheets, etc. This mill is geared for a maximum rolling speed of about 2000 ft. per min., and the drive consists of one 1500 hp., 250/500 rpm. and three 2500 hp., 187.5/375 rpm., mill motors, and 625 hp., 312/1100 rpm. winding reel motor. Direct current power is supplied at 750 volts by a 7000 kw. synchronous motor generator set.

Various other cold reduction mills have been installed or ordered, all leaning to the higher speeds, which have already reached 2500 ft. per min. or more. The top to be reported so far is a mill, on order, with a maximum delivery speed of 3850 ft. per min. This five-stand mill, built to roll tin plate gauges, will be driven by motors rated 800 hp., 2000 hp., 2500 hp., 2500 hp. and 3000 hp., respectively; the tension reel, by a 600 hp. motor. Power will be supplied by an 8000 kw. motor-generator set. In order to keep the inertia of the drives low, all motors except the 800 hp. unit used with the stand No. 1 are made for direct connection. The 2500 hp. and 3000 hp. motors (stands 4 and 5), as well as the 600 hp. reel motor, are built as double armature machines to reduce still further their WR^2. This mill—like the majority of new cold strip mills—will be equipped with tensiometers between the stands.

A single stand reversing cold mill, with a winding reel at either side, is being equipped with regulating tensiometers for controlling accurately the tension on the reels, throughout an extremely wide range of tension required in this case.

To keep pace with the greater output of the higher speed cold reduction mills, the newer skin pass mills

Aided by improved electrical equipment and control, new cold mills are using faster acceleration and higher speeds.

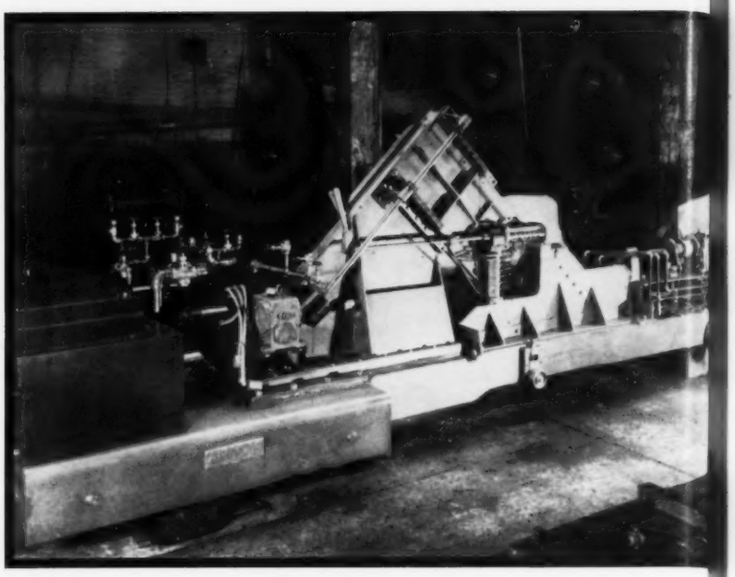


also are being designed to operate at increased rolling speeds. One tinplate producer has completed installation of three two-stand skin pass mills, laid out for normal operating speed of about 2500 ft. per min. and incorporating a number of novel features in the electrical equipment. Each mill consists of two working roll stands, with feed reel and tension roll device at the entry side to exert back tension on the strip entering the mill, and a second tension roll device and winding reel at the delivery side to exert forward tension on the strip leaving the mill. All of the mill, reel, and tension device motors and drag generators are designed to operate at the mill speed, and are direct coupled, thus eliminating all reduction gearing, and reducing WR^2 to a minimum. The upper and lower rolls of each of the entry and delivery tension roll devices are individually coupled to separate motors (drag generators) making up twin-motor drives, thus enabling the use of rolls of slightly different diameter and assuring better equalization of the tensions developed by the two rolls than was possible where the upper and lower rolls were connected to the same motor. On each mill there are provided three automatic tension regulating tensiometers, acting to control the entry tension device drag generators, No. 1 stand mill motor, and delivery tension device motors, so as to maintain constant tension on the strip as it enters the No. 1 mill stand, between No. 1 and No. 2 mill stands, and as it leaves the No. 2 mill stand, thus assuring uniform processing throughout the length of each strip. One single stand skin pass mill has been installed with individual drive of the upper and lower rolls of the entry and delivery tension roll devices.

Automatic regulating tensiometers have been applied on several cold reduction and skin pass mills, and many of the new installations are provided with *IR* drop and armature demagnetization compensation control, previously described.

An interesting feature of the past two years is the phenomenal growth of continuous butt-weld pipe mill installations, there now being eleven mills of this type in the United States. Although the first mill was installed at Butler, Pa., in 1922, use of the process first spread abroad, in 1932 and 1933, the principal expansion in this country being confined to 1939 and 1940. This equipment has been standardized to a considerable extent, and consists of an uncoiler, a roller leveler, a flash welder and trimmer, a looping table, a furnace about 165 ft. long with recuperators, a forming and welding mill, an automatic hot saw, conveyors, a descaler, and cooling beds. The later installations are of two sizes, the more common for pipe sizes of ½–3 in., with a maximum speed of 400 ft. per min., and an annual capacity of about 85,000 tons. The larger size produces pipe in sizes of 1–4 in., with maximum speed of 300 ft. per min., and an annual capacity of about 150,000 tons.

In connection with the supply of suitable skelp for use in the butt-weld pipe mills, a coil conveyor of interesting design was developed. It is necessary that the specially rolled skelp edges not be damaged and that the concentricity of the coil be maintained. Handling is complicated by the large coil diameters (up to 54 in.) with only 6 or 8 in. width. This particular installation was worked out by the use of a stacker unit in combination and synchronized with a down tilter from a water spray conveyor, which discharges on to a storage conveyor situated at right angles to the spray conveyor. Controls are automatic, with provision for manual operation.



Increased attention is being given to the use of hot scarfing machines for bloom and slab surface preparation.

The use of flame scarfing as a means of removing surface defects from blooms and billets is expanding, the percentage of steel conditioned by this method increasing steadily. Flame scarfing removes a production bottle-neck, is easier and more agreeable to perform, and in some cases will show up defects which would be unnoticeable in chipping. Further development along this line has centered interest around the hot scarfing machine, wherein the material is completely desurfaced while passing along a roller table either in line with, or adjacent to, the blooming or slabbing mill. Machines of this type remove a depth of $\frac{1}{32}$–$\frac{1}{16}$ in., with the material moving at a speed of 120–160 ft. per min. A number of these installations have already been made, and more are on order. For both types of scarfing, the trend is toward a central oxygen plant wherein liquid oxygen is gasified, and subsequently distributed in a piping system specially designed to handle oxygen. Fuel gas is usually acetylene, with the central generating plant again in evidence, particularly in the larger plants. Some plants, however, use fuel gases of the more common types, such as natural gas, coke oven gas, or a mixture of the two, with satisfactory results.

Flame descaling of steel surfaces has proven satisfactory for certain types of work on most grades of carbon and low alloy steels. The process as used in the steel plant may be fitted into a production line and may be supplemented by subsequent pickling for a complete cleaning job. In flame descaling of blooms, billets and slabs, the oxy-acetylene torch carries brush-type tips, positioned so the enveloping flame completely covers the scaled surface. The tips are mounted on wheeled carriages or hard-faced skids, and are traversed over the surface at 10–20 ft. per min. The high temperature rapidly heats the scale without over-heating the base

metal, and the resulting differential expansion causes the scale to lift, crack and fly off in small pieces.

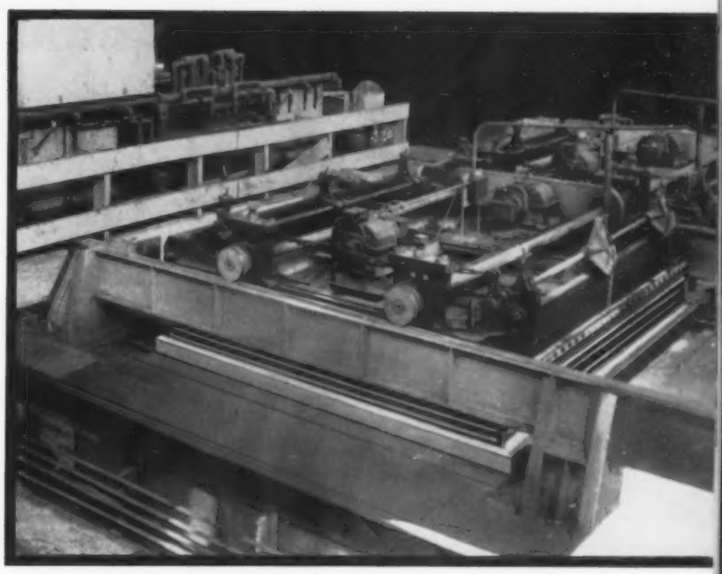
A new portable oxy-acetylene bar-cutting machine answers a great number of production cut-off problems. It employs a self-contained power unit with hydraulic motion and speed controls to provide smooth blowpipe movement and wide variation in cutting speeds.

FURNACES

The trend in the metallurgical industry is toward higher temperatures, which demand refractories of an improved or a completely changed nature. Many changes in the method of manufacture have contributed materially to the service rendered by refractories. Trends may be noted in the development and application of unburned magnesia brick and chrome-magnesia brick. Experimentation in the substitution of products made from dolomite, either with or without additional reacting substances, for the usual basic refractories, has been carried on.

Another development of interest is the increasing use of rammed basic refractories for furnace construction and maintenance. This is particularly noticeable in the hearth construction of steel-making furnaces.

The demands for higher quality in steel mill products have focused the operators' attention to the great importance of the various heating operations, and in many cases has led to the modernization of existing furnaces or the installation of new ones. A number of new soaking pit installations have been made or planned during the past year, the majority of which are of the one-way-fired type. Several new continuous furnaces were also built in connection with existing mills. Closer control of all heating processes is evident, as a part of the general quality control systems.



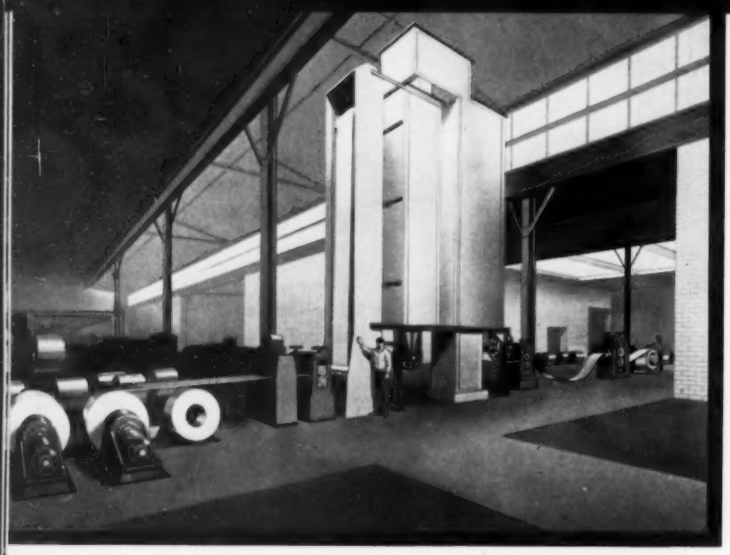
In this new design, a gas-tight seal between soaking pit and cover is effected by use of a sealing curtain.

Demands for higher steel quality have focused attention upon heating operations, leading to considerable improvement in that field.

A soaking pit cover of new design affords a gas-tight seal through the use of a suspended movable apron or sealing curtain around the periphery of the cover. The apron engages sand troughs, and only the apron is moved vertically. The relatively light weight of the apron requires little power for its movement, which is entirely independent from movement of the cover itself, although the two motors are controlled from a single master switch and electrically interlocked for proper sequence of operation. The tight seal prevents flame impingement upon metal parts, consequently avoiding warpage or burning out.

One producer specializing in the high chrome and nickel alloys has expanded its capacity during the past year, doubling the capacity of three years ago. In connection with this project, four gas-fired ingot heating furnaces of the in-and-out type were installed, designed to heat cold alloy ingots 12 in. x 12 in. x 50 in. up to about 2100 degrees F. The furnaces are served by a floor type charging and drawing machine with a revolving trolley. Two gas-fired billet heating furnaces were also installed, in addition to a gas plant consisting of three clean gas generators, operating on rice anthracite or coke.

In the latter part of the year, the first two installations of an entirely new application of radiant tube heating were made. This new design is effected by placing the firing tubes, as an integral part, within the inner cover of the furnace, so that they may release



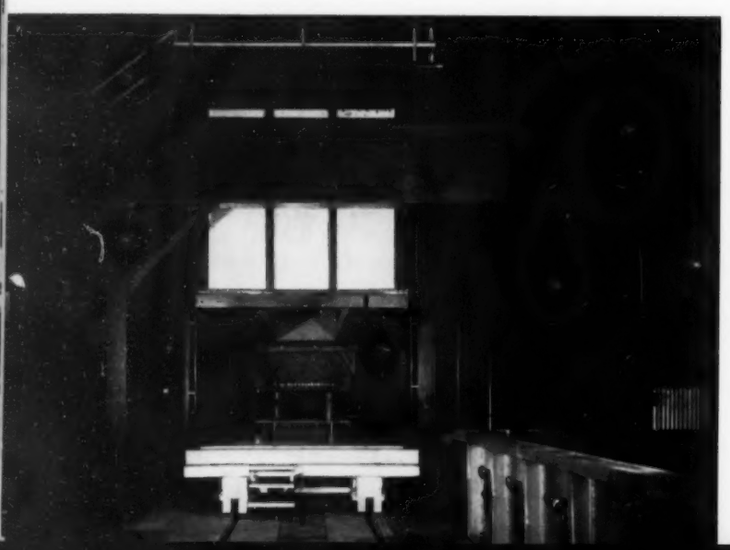
The temper tower continuous strip annealer has been used to replace electrolytic cleaning and box annealing in one plant.

their radiant energy directly to the charge. The waste gases, instead of being discharged directly to the atmosphere as in the former design, are now discharged within the furnace bell. In furnaces using recirculation within the inner cover, the recirculated gases now pass directly over the radiant tubes, increasing the heat transferred by convection.

In effect, this new design makes every inner cover a furnace, while the insulated furnace bell becomes merely a heat retainer. Among the advantages claimed for this unit is the adaptability for very fast cooling by blowing air through the firing tubes. The faster cooling thus obtained assures the adequacy of three bases per unit, with consequent reduction in cost and floor space. Actual results from the first units in operation show an immediate fuel reduction of 10 to 15 per cent, and an increase in production of 10 per cent.

The firing tubes in the new design are vertical in position, and shaped in an inverted U, making a complete bend within the inner cover, or retort, before discharging gases at the bottom. Dual pressure burners are used, which can be accurately adjusted to produce exactly the length of flame desired in the tubes. The

This electric resistor furnace, for heat treatment of alloy steel, is designed to handle charges up to 18,000 lb.



burners are totally enclosed and operate in a manner so that complete combustion can be obtained even at minimum turndown position.

A new method of continuously annealing strip for tin plate is of interest. For this process, the equipment which is termed a continuous temper tower, consists of pay-off reels, a seam welder, pinch rolls, a looper, a vertical annealing furnace, cooling towers, pinch rolls, a second looper, a shear, and a recoiler. The furnace, about 30 ft. high, is heated by radiant tubes in which natural gas is burned. Normal operating temperature of the furnace is 1300 degrees F., with a maximum temperature of 1700 degrees F. In the water-jacketed cooling towers, strip temperature is reduced to 200 degrees F. or lower. The equipment will handle strip .0086–.025 in. thick and up to 38 in. wide, and has a speed range of 75–300 ft. per min. Advantages claimed for this process include greater uniformity of annealing and of strip surface, a bright anneal, better metallurgical control, elimination of the conventional electrolytic cleaning, reduced temper rolling due to small grain structure, and a shorter time cycle.

Open-flame annealing of wire has permitted higher speeds in a continuous process. The anneal is automatically controlled by a special device which actually "feels" the wire as it passes through the line. Temperature and proportioning controls are applied.

Direct-fired radiant gas combustion systems are being increasingly applied to heat treating furnaces. This system is particularly advantageous in large furnaces, where radiant burners may be located in a flat suspended roof, giving a high degree of temperature uniformity throughout.

A modification of this use of direct-fired radiant heat, as recently announced, consists of firing through porous refractory radiant blocks, instead of through open burner ports. Premixed gas and air are led to the back of the radiant block and distributed over its surface through a web system of passages. The block has sufficient porosity to permit the fuel-air mixture to pass through. As the block becomes heated, combustion is practically completed before the gases emerge from the block. Temperatures up to 1950 degrees F. have been obtained, and it is expected that forging temperatures may be reached.

A recent development is a new and improved type of tubular furnace, used for normalizing up to 1750 degrees F. and for drawing at temperatures as low as 800 degrees F., holding the same high degree of uniformity at both the lower and higher temperatures. The furnace is a horizontal cylinder, about 100 ft. long, and the tubular shape of the chamber, together with the tangential method of heat application, is responsible for the high degree of uniformity of temperature. This furnace is designed with a driven roller hearth, and burners are placed both above and below the driven alloy rollers, firing tangentially into the chamber.

The use of special protective atmospheres has grown rapidly in heat treating applications. One of the later developments in this field is an atmosphere for the protection of medium and high carbon steel during heat treating. The atmosphere consists of approximately $\frac{2}{3}$ nitrogen and $\frac{1}{3}$ carbon monoxide with only traces of carbon dioxide and water vapor. It is prepared by passing air through heated charcoal inside of a vertical

refractory retort which is externally heated. The resultant gas is taken off at a certain definite position in order to eliminate undesirable constituents. One pound of charcoal will produce approximately 100 cu. ft. of atmosphere gas. Tests and field trials have indicated that this gas is an excellent protection for both high carbon and alloy steels.

In order to assure a constant quality of protective atmosphere for bright annealing furnaces, a control system has been developed which compensates for variations in gas or air supply to the atmosphere generator. The bright annealing gas as generated is sampled continuously, the sample passing through a thermal conductivity analysis cell which develops a potential depending on the composition of the gas. When the composition changes, the changed potential causes a controlling potentiometer to function, changing the adjustment on the gas carburetor and restoring the atmosphere composition to the desired point.

One major producer in the Pittsburgh district is now tempering wire, for special mechanical springs, by an electric direct resistance method. This process consists of passing sufficient current through the wire to heat it to the desired temperature. From the feed reels, the wire passes through tension rollers, then through two molten electrical contacts which are held at a constant pre-determined temperature. The resistance of the wire itself, under a constant flow of current of controlled voltage and amperage, causes a uniform increase in temperature of the wire to within very exact limits. The second contact bath also serves as a primary quenching bath, and is immediately followed by an oil quenching bath. A subsequent molten tempering bath gives desired physical properties and fatigue values. The close control of time and temperature obtained in this process results in higher, more uniform physical properties than is usual with other methods.

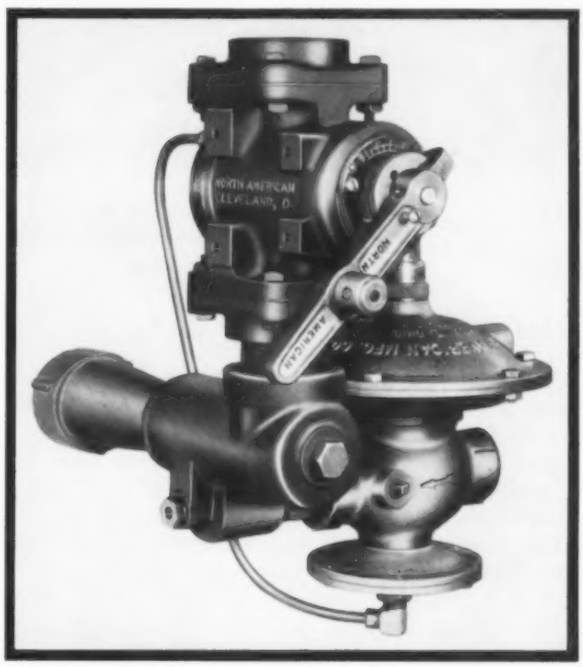
Some interesting results have been obtained from an anti-scaling coating which may be applied to carbon steel parts which are subjected to high temperatures. The compound consists of a specially compounded vehicle and a pigment mixture consisting of nickel and chrome. After application, the pigment fuses on and actually penetrates the steel surface at high temperatures. Service trials on steel inner covers for portable annealing furnaces show a very marked protection to be obtained in comparison with non-treated covers. Similar results have been obtained on cyanide pots, carburizing pots, etc. The material is applied by brushing, on a sand-blasted or pickled surface.

Submerged combustion is now a proven method for the heating of pickling tanks and coating baths. The heating is extremely efficient because of the intimate contact between hot gases and liquid, and the low temperature of the heating medium leaving the bath.

INSTRUMENTS AND CONTROLS

Combustion controls and instruments are now generally mounted on central panels which carry all of this equipment for a furnace or sometimes for a group of furnaces, rather than the hit-or-miss mountings of a few years ago. A constant current of improvement progresses in instruments and controls, tending to give ruggedness combined with sensitivity. A newly developed regulator for metallurgical furnaces incorporates an unusual feature which is said to give fast, accurate response to slight changes, with complete stability. The pilot valve is kept spinning continuously through the action of a small stream of oil directed against a series of vanes fitted to the pilot. This continuous motion eliminates the effect of static friction, which normally would require a greater force to start movement than is required to continue the movement. Thus, sensitivity is increased and the tendency to overtravel is overcome.

Another manufacturer brought out a control for furnaces using more than one fuel. This control includes devices actuated by static air pressure, for automatically and mechanically measuring the sum of the flows of the two fuels, so that combustion air can be automatically proportioned. The air regulator has a measuring element containing an adjustable weighbeam. Fuel-air ratio is changed by operating an adjuster on the panel front without stopping operation of the regulator.



This motor-operated control produces an air-gas mixture of constant, but adjustable, proportions over the entire operating range.

Constant proportioning of the air-gas mixture is claimed over the entire operating range for a new motor-operated valve. Gas is reduced to atmospheric pressure by a special regulator, while part of the energy in the air stream is used to aspirate the gas, so that a fixed relationship exists between flows of the two gases at all times. The aspirator is sufficiently flexible to afford some correction for varying pipe resistance, etc., while the control valve has an adjustable port that can be set to insure effective control of the air over the whole operating range.

Operating speeds of 10–135 ft. per min. are attained with modern straight-line galvanizing units under variable voltage control.

Many important improvements were made in air-operated controllers for temperature, pressure, humidity, or liquid level, either operating at one definite control setting or varying according to a pre-determined schedule on a time cycle. In electrically operated controllers, new combinations of current interruptors and anticipatory devices produce improved performance. Electronic relays are widely used in electrically operated control systems.

Furnace pressure and draft instruments using a sensitive, dry-bellows type of diaphragm are widely used for ranges up to 50 in. water column, beyond which a helical element may be used.

Remote metering and control has received considerable attention, and several improved methods have been developed, suitable for various distances up to the 100 miles or more obtained by telephone and carrier current.

Development has proceeded on various instruments for the analysis of gaseous atmospheres, using chemical or physical properties of the atmosphere. Instruments for measuring oxygen, carbon dioxide, or combustible content are available, all materially improved over those of a few years ago. The field of application of such instruments has greatly expanded in recent times, and a sufficient degree of accuracy and reliability will greatly increase their use.

A new instrument has been announced for oxygen measurement and control, which may be used to control oxygen content in chemical processing, to measure oxygen content of natural, coke-oven and blast furnace gas, or to measure excess air in products of combustion from gas, coal, or oil burners. This analyzer is in the form of a voltiac cell. One copper electrode is immersed in an electrolytic solution, while the other is in the form of a ring, which slowly revolves with part of its periphery in the electrolyte and the remainder exposed to the gas sample. Oxygen in the sample reacts with the copper to form oxide, which then enters the electrolyte and sets up a potential proportional to the oxygen content of the gas sample. The result is read on a specially calibrated recording potentiometer.

PROCESSING AND FINISHING

The increased output from the modern hot strip mills, the capacity of which has considerably exceeded that of the attendant finishing capacity, has materially stimulated activity in the field of finishing and processing lines. Throughout the industry various units of this type have been added, practically all of which operate at higher speeds. Until recently, most electrolytic cleaning lines operated at speeds not exceeding 1000 or 1200 ft. per min. Improvements in the mechanical and electrical equipment have shown the feasibility of operating such lines at much higher speeds, and cleaning lines are now being installed to operate at 2000–2500 ft. per min. under special variable voltage control. In order to obtain the necessary close coordination of speeds of the various component drives during the operating cycle, *IR* drop compensation control is being applied to many of these units.

A definite movement is to be noted toward the installation of modern straight-line sheet galvanizing units, where the various parts of the galvanizing machine, the spangle conveyor, and the cooling conveyor, washer and drier are combined into a continuous

line, under close synchronization. Such units are somewhat over 100 ft. in length, and recent installations use a combination of voltage control and field control of the various drive motors, giving extremely close synchronization, and at the same time, a speed range of 10–135 ft. per min.

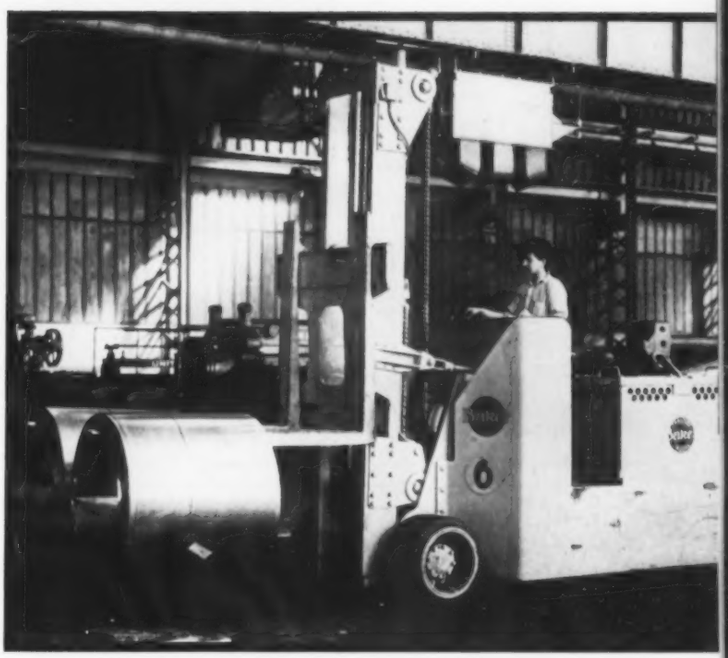
Threatened curtailment of tin imports has evoked considerable activity in the development of suitable substitutes or of processes through which less tin will be required. Possible processes include silver plating of the steel, application of black lacquers, and electroplating with nickel and tin. Several commercial smelters have been constructed, which may be used for the smelting of Bolivian ores.

Tinning by electrolytic methods has been under development for some time, and reports from several sources indicate that the process is commercially practical. Some trials also have been made along the lines of electrolytic galvanizing.

Shearing lines also show somewhat higher speeds, and many units of this type are provided with variable voltage control systems. Increased use of the pin hole detector is to be noted on tin plate shearing lines, the detector being hooked up to the classifying mechanism so as to automatically dispose of the faulty material.

Advances have been made in all forms of material handling equipment to meet the increased flows of product through the plants. Special conveyors of various types, both gravity and driven, have been developed to meet the problems at hand. Trucks, driven from storage batteries or from combustion engines, are available in larger sizes, to take care of the greater loads imposed. Vertical lift bosh trucks have been applied to tin mill service, using automatic covers to prevent the solution from slopping out of the bosh. Covers are adjustable in order to meet varying bosh height.

In general, truck development during the past year has been largely in the line of improvement of the basic types previously offered. Among these improvements are remote contactor control, heavy duty drive motors, improved steering, increased lifting speeds, and sturdier construction. One manufacturer has just announced a new five ton low-and-high-lift platform truck, of completely new design and construction, with many features contributing to low maintenance.



Trucks for intra-plant material handling have been generally improved as to strength, speed, and operating characteristics.

ELECTRICAL DEVELOPMENTS

Standard specifications for the d-c. mill motor have been revised, and were published in the IRON AND STEEL ENGINEER for August, 1940. The standard d-c. mill motor is now the short frame motor, the long frame motor being considered as a modification of the standard. Basic 1 hr. 75 degree C. totally enclosed ratings of the standard line are now 5 hp., 7½ hp., 10 hp., 15 hp., 25 hp., 35 hp., 50 hp., 75 hp., 100 hp., and 150 hp. A.I.S.E. frame numbers have been adopted as a convenient and positive means of identifying a particular size, irrespective of the make. Complete ratings and dimensions are given in the foregoing reference.

To meet the requirements of high speed operation of shearing lines, one manufacturer has developed an a-c. motor for up-cut shears. This motor has a very low inertia rotor, a relatively high torque capacity, and contains an integral small blower unit. Several motors of this type are in service, with satisfactory results. This same company has also developed a drive for runout tables or conveyors, wherein the individual roller drive motor is essentially mounted on a shaft extension of the roll itself. The motor contains its own bearings and is built as a hollow shaft motor, the hollow shaft slipping over the shaft extension of the roll. This construction eliminates the use of semi-flexible couplings and motor mountings.

The large volumes of ventilating air circulated through electrical equipment for cooling require that the air be well cleaned in order to avoid excessive dirt being carried into the machines. Many types of air filters have been used, and more recently, electro-static cleaning units, which are particularly effective on the fine particles, have been employed. Although a recent development, steel plant installations of this equipment now total about one and one-half million cu. ft. of air per min. The first steel plant installation was made for purifying the air used for ventilating main drives and motor-generator sets in a mill in the Ohio River valley, and consists of two electrostatic units, each rated at 72,000 cu. ft. per min., and involving 120 36 in. cells grouped four high by 30 high. One smaller unit is rated at 45,000 cu. ft. per min., and is composed of 76 36 in. cells grouped four high by 19 wide. These units operate at an efficiency of about 90 per cent.

Another air cleaning unit combines a self-cleaning viscous air filter of conventional vertical curtain design with electrical precipitation. The traveling curtain serves both as a medium for the impingement filter and as collector plates for the precipitator. The curtain is flexible, and is thoroughly insulated and provided with

means for applying electrical potential of opposite polarity to adjacent plates. This combination of the two methods of cleaning is stated to be very effective.

Developments in switchgear and control equipment have been largely toward centralization and combination. Equipment has also been improved by more rugged designs and more durable materials. Designs have tended toward greater accessibility and improved appearance. Greater use of silver plating and of solderless connectors is to be noted on current-carrying parts of switches and allied equipment. One manufacturer has announced a standardized motor control unit which permits all needed types of control devices to be organized in a central locker-like cabinet. The cubicles are made in various sizes and any desired combination of standard control equipment may be accommodated. Units are assembled either with all wiring busses, supports, terminals and interconnections already made, or with provisions for wiring it on the job. A door swing-out feature facilitates wiring and change-overs. Sections may be installed in almost any desired formation, and no special wall or floor preparations, or fabricated supporting structure, are required. Standardized uniformity, appearance, flexibility and economy are thus afforded.

A new synchronous motor control, featuring the slip-cycle impedance relay, permits accurate control of synchronizing speed, so that the field cannot be applied until the motor has reached a speed at which it can synchronize its load. The relay may be adjusted for the speed desired, and undesirable current and torque fluctuations are avoided. The slip cycle impedance relay also prevents pulsations in case of motor pull-out by disconnecting the power, or, if automatic resynchronization is desired, the field.

Magnetic arc-quenchers for use on circuit breakers have been improved by use of magnetic vanes, placed on the outside of insulating barriers. The vanes are magnetized with the opening of the arcing contacts, and the magnetic field thus set up forces the arc into an extinguishing chamber. Insulating barriers within the chamber cool the arc, create a turbulent gas condition, and provide a cooling draft across the arc core.

Compressed air circuit breakers, wherein a jet of air is used to quench the arc, have also found favor in use.

A new line starter, designed for frequent operating or jogging, or for regular starting service, consists of a multi-pole a-c. contactor and a two-element thermal overload relay. The design provides for long life, having heavy silver contacts, and a thermal overload relay is of solder pot design.

A combined across-the-line starter and disconnect switch, for use with squirrel cage and single phase motors, has also been announced. These units, in sizes running from 7½ hp. to 200 hp., are provided with overload protection and with various types of cover control. The combined construction saves wiring and conduit work, while front operation of the unit permits close gauging.

Many steel plants have adopted synthetic-sheathed cable in place of braided types. This type of protective covering is now used over practically all of the various basic rubber insulations, and is highly resistant to heat, oil, and chemicals.

A new type of switchboard wire uses an extruded free-stripping synthetic insulation over the tinned copper conductor. This in turn is tightly encased by a layer of purified asbestos applied by a patented felting process, over which is a flame-proof, abrasion-resistant outer braid. This wire can take sharp bends without cracking the insulation or disturbing concentricity; it is highly resistant to moisture, and is not affected over a considerable temperature range.

Glass insulated magnet wire has also been developed, using improved new varnishes which give harder finish and increased resistance to abrasion, with higher dielectric strength.

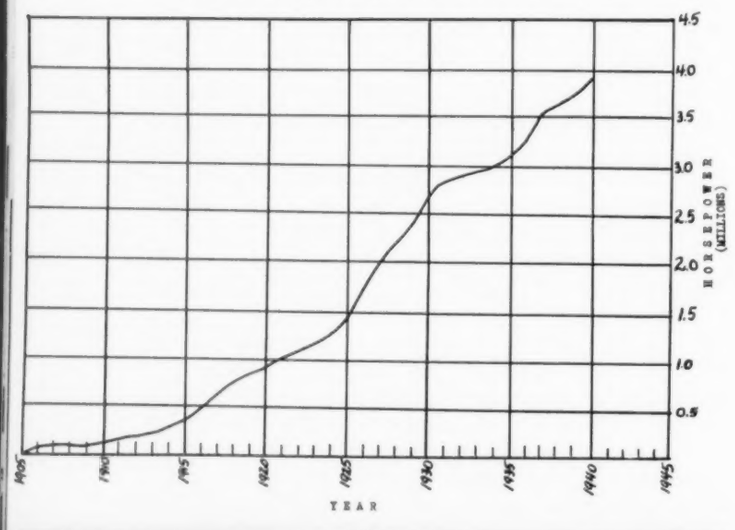
A building wire insulated with a plasticized polyvinyl chloride offers a much smaller diameter than ordinary rubber covered wires, so that more can be installed in a given conduit.

An improved weatherproof wire, recently announced, has a heavy layer of high voltage rubber insulation between the conductor and the braid, giving very high electrical values even when thoroughly wet.

Carbon brushes are available with a resilient pressure pad secured on the holder end at the point of contact with the pressure finger. These pads eliminate or reduce the destructive effects of severe vibrations. The pads are stated to be very durable, retaining their resiliency throughout the brush life.

Announced during the past year is a new type of battery of kathanode design, assembled in steel tray complete with steel covers. This construction eliminates the wood tray and means that where formerly the battery was assembled in wood tray and carried in a special compartment, the steel tray now serves both purposes. This battery fulfills the requirements for an extra capacity battery for propulsion of heavy duty electric trucks, particularly the new center control fork type equipment, and is available in sizes from 15 to 21 plates with capacities ranging from 700 to 1000 ampere hours at the 8 hour rate of discharge.

The cumulative curve of main drive motors over 300 hp. shows a present total of 3,901,215 hp. Eighty-eight motors (118,850 hp.) were added in 1940.



The trend toward more battery capacity in proportion to size is to be found among other manufacturers. This is in response to increased use of industrial trucks for carloading, which imposes certain dimentional limitations.

The use of trucks on full-time operating schedules has necessitated speedy battery changes, so that one battery may be on charge while another is in operation. Changing has been expedited materially by the assembly, at the factory, of batteries in steel cradles, or if desired, in demountable steel boxes which form the battery compartment of the truck.

Considerable development has been made during the past year in equipment providing comfortable working conditions for overhead crane operators. This problem, especially on hot metal cranes, has long been a source of employee dissatisfaction, and also has been injurious to health and operating efficiency. Equipment is now available that will provide as much as a 40 degree F. temperature reduction of air entering the cab, in such quantities as to successfully combat the infiltration of hot, fume laden air. Filters are provided for cleaning the incoming air of dust and dirt as well as fumes, smoke and gases that are injurious to the health of the operator. This same equipment includes an electric heater that provides a flow of filtered air heated to a satisfactory temperature during winter operation. The entire equipment can be either automatic or adjusted to his personal requirements by the operator.

Also available are ventilating heaters for general crane application which circulate filtered heated air at floor level so that even at 10 degrees below zero the operator is kept warm and efficient. The same unit is utilized during the summer months to direct an increased flow of air approximately at waist level so that the air in the average cab is completely changed at least once a minute. These units are low cost and can be applied to inside as well as outside cranes with equally beneficial results.

Crane signals are becoming standard equipment with a majority of steel plants as they have proven successful in reducing accidents, by advising at all times the condition of each crane on the runway.

Fluorescent lighting equipment is receiving wider application. The units are available in various sizes, and a variety of holders is available. Power factor correction is essential to the economical operation of these lamps, and most of the units have provision for this in the operating apparatus. Refinements are also to be noted in the incandescent lamp fixtures for all types of service.

Many cranes have been rebuilt, with modern enclosed controls, and often to considerably increased capacity.

MECHANICAL DEVELOPMENTS

The relatively small amount of replacement and modernization of boiler plants during the past decade has resulted in the steel plants being faced with the replacement of a large amount of boiler heating surface that is 25 to 30 years old, more or less obsolete, and certainly uneconomical.

A partial survey of activity in the steel plant boiler field shows that over half of the propositions under consideration fall in the low pressure range of 160–275 lb. A substantial number falls in the 400–600 lb. pressure range, with some for higher pressures up to 975 lb. Some of these are designed for topping turbines. Pulverized coal, either alone or with blast furnace gas or coke oven gas, seems to be the favored fuel choice, with coal or coke breeze on chain grate stokers in second place. Combination firing imposes several more or less contradictory conditions upon boiler design. The greater gas volumes involved in the combustion of blast furnace gas should have large furnace volume, adequate gas passages, and not too much heat recovery surface, in order to avoid excessive draft loss. In some cases where both economizers and air heaters are installed, they may be arranged for by-passing or parallel operation when burning gas, and for series operation when burning coal. Water-cooled side walls are widely used in order to avoid fusing temperatures with ash of low-fusion characteristics.

One recent installation burns coke breeze and river anthracite in layers on traveling-grate stokers, while blast furnace gas, when available, is introduced through the side wall at the back end of, and well above, the stoker. Details of a number of other recent boiler installations were discussed in a paper, "Some Modern Applications of Boilers in Steel Mills," by D. N. Mauger, in the IRON AND STEEL ENGINEER for October, 1940.

Considerable attention is now placed on the removal of silica from boiler feed water during treating. Precipitation of magnesium salts, present either naturally or through introduction as a reagent, gives a considerable silica reduction in the hot process softener. Several special materials are marketed, consisting primarily of magnesium oxide, sometimes mixed with calcium hydrate, designed for silica reduction in the hot process softener.

Removal, from water, of carbon dioxide, hydrogen sulphide, sulphur dioxide, methane, or other undesirable gases may be effected by the use of a "decarbonator," a stack of staggered trays, of varying height, over which the water is sprayed and cascaded down, as an air current passes up through the tower. These units, not unlike a forced draft cooling tower, may also be used as aerators for the removal of iron.

Wide application of anti-friction bearings was made on tables for blooming, slabbing and strip mills, as well as other mill auxiliaries. A great many open hearth charging buggies and ingot buggies were changed over to anti-friction bearings, and will cranes and mill motors are almost universally so equipped.

Centralized lubrication is available to machine tools and other small units of equipment through grease systems using the usual piston displacement principle of measurement employed in large systems. The pumps, valves, couplings, etc., used in these systems are proportionately reduced in size. The valve has but two moving parts, contains no springs or check valves, and is fully adjustable.

Considerable attention has been given to the development of small lubricating devices to give positive, economical lubrication to small units where the larger centralized systems are out of the question.

A wide variety of designs is to be noted in the smaller speed reducers. The heliocentric design uses no gears, pinions, or worms to obtain the reduction, yet provides a positive, non-slipping drive giving a ratio as high as 80:1 in a single stage reduction. Another type includes a helical-ground 13:1 reduction unit which is mounted on the power shaft of the driven machine, supplemented by a belt drive from the motor shaft. Variable speed may now be obtained on very small drives (up to 1½ hp.) through a unit consisting of two cone-shaped discs, between which runs a V-belt. Lateral adjustment of one of the discs provides a countless number of operating speeds.

The national defense program requires numerous large hydraulic presses for forging operations. These presses are hydraulically operated, and for the high pressures involved reciprocating type pumps are used. Depending upon the forging operation, the presses require rates of flow which may be uniform but intermittent; variable; or uniform, variable, and intermittent. A reciprocating pump is primarily a positive displacement machine giving a constant rate of flow. In order to meet the press demands for various rates of flow, the reciprocating pump is controlled through a synchronized unloading and loading device. With this device, the pump and motor operate continuously, and the pump is unloaded and loaded by maintaining the suction valves either inoperative or operative. The device was formerly controlled entirely by the mechanical action of air pressure and through an air operated distributor, but a new electrically controlled device using a pressure governor and solenoids, has been applied on many pumps.

Synchronized unloading is the interruption of the pump delivery, in such a manner that unloading is accomplished by a gradual deceleration of fluid delivery and power input from full to zero, coinciding with the diminishing rate of flow of the last plunger displacement. Synchronized loading is the resumption of the pump delivery in such a manner that loading is accomplished by a gradual acceleration of fluid delivery and power input, from zero to full, coinciding with the increasing rate of flow of the first plunger displacement into the pressure system.

Unloading is accomplished at the end of the discharge stroke of the last plunger, and loading begins at the beginning of the discharge stroke of the first plunger. This basic and inherent characteristic definitely eliminates shocks and loss of pressure fluid. Either unloading or loading is accomplished within one-half of a pump revolution. Maintenance of this device is negligible not only because hydraulic shocks are eliminated but also because the loading and unloading mechanism is on the suction or low pressure side of the pump rather than the discharge or high pressure side. Hence, the pump may be unloaded and loaded with any degree of frequency.

For handling acid and waste acid, pumps, constructed of acid resisting material, are available at moderate cost. Such pumps may have a life of 15 to 20 years, as compared with a two year life obtained from cast iron pumps.

In all equipment, increased use of special materials, designed to give longer life, is evident. Shaft sleeves, extremely resistant to corrosion and wear, are used on centrifugal pumps. Valves and similar equipment are fitted with special alloy seat rings and plugs, which resist wear and wire-drawing.

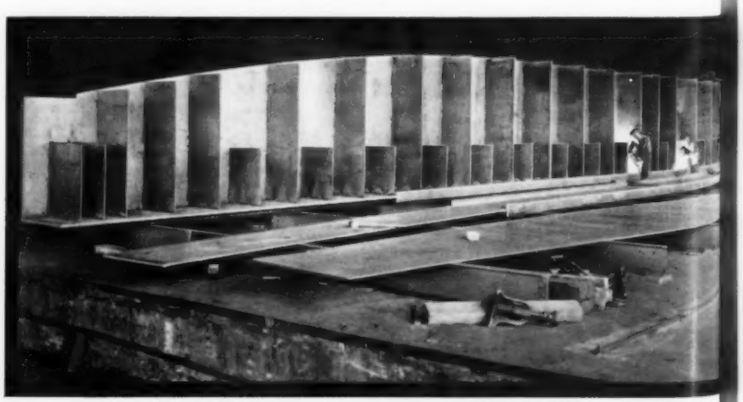
WELDING

Welding, in its various forms, is making a definite contribution in the general speed-up of production. In almost every phase of construction and fabrication, welding is more broadly applied, sometimes replacing castings, sometimes supplementing them. Arc welders have reached a capacity of 4000 amperes, which enables them to make a butt weld in heavy plate in one pass on each side of the material. Experiments on sections ranging from ½ to 2¼ in. in thickness have not required full capacity of the unit.

An all-purpose portable a-c. arc welder for general utility service and production welding has been introduced recently. Operating on 220 or 440 volts, the units are completely self contained. From 20 to 250 amperes welding current is available in twenty-seven steps proportioned to meet the requirements of welding with a wide variety of electrode types and sizes.

Several models of engine-driven arc welders have been

The growth of welding is typified by this all-welded crane girder, said to be the largest in the world.



Tabulation of Cranes, Trolleys and Bridges Purchased in 1940

Number cranes	CRANE CAPACITY Max.	Aux.	TYPE OF BEARINGS Completely anti-friction	Partially anti-friction	Plain	TYPE OF GEARING Spur and worm	Spur	Spur and helical	Spur and herring-bone	Type of current	Number motors	Type of crane	Span	Remarks
2	2	..	Yes	...	...	...	Yes	...	...	d-c.	3	Standard overhead	39′10″	
1	2	..	...	Yes	...	Yes	...	...	...	d-c.	5	Soaking pit	77′ 0″	
1	3	..	Yes	...	...	Yes	...	...	...	230 d-c.	3	Standard	37′ 0″	
1	3	15 std.	Yes	...	...	Yes	...	...	...	230 d-c.	6	Soaking pit	76′ 0″	15 ton hoist auxiliary
2	5	..	Yes	...	...	Yes	...	...	...	230 d-c.	4	Special, semi-gantry	41′ 6″	
1	5	..	Yes	...	...	...	Yes	...	...	230 d-c.	5	Floor charger	19′ 8″	
1	5	..	Yes	...	...	...	...	Yes	...	d-c.	4	Mill	97′ 1⅛″	
1	5	..	Yes	...	...	...	Yes	...	...	d-c.	2	Electric overhead traveling	40′ 0″	
1	5	..	...	...	Yes	...	Yes	...	...	d-c.	4	Open hearth charging	24′ 6″	
1	5	..	Yes	...	...	...	Yes	...	...	d-c.	3	Mill	72′ 0″	
1	5	..	...	Yes	...	...	Yes	...	...	d-c.	3	Mill	103′ 3½″	
4	5	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Mill	70′ 0″	
1	5	..	Yes	...	...	...	Yes	...	...	d-c.	5	Open hearth charging	14′ 9″	
1	5	..	Yes	...	...	...	Yes	...	...	d-c.	4	Standard overhead	63′ 6″	
1	6	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Mill	69′ 0″	
1	6	..	...	...	Yes	Yes	...	...	...	230 d-c.	2	Gantry	18′10¾″	
1	6	..	...	...	Yes	Yes	...	...	...	230 d-c.	2	Cover lifting gantry	14′11″	
1	7½	5	...	...	Yes	...	Yes	...	...	230 d-c.	5	Soaking pit trolley	.....	Trolley
1	7½	20	...	Yes	...	Yes	...	...	...	230 d-c.	8	Open hearth charging	60′ 0″	
1	7½	..	...	Yes	...	...	Yes	...	...	d-c.	5	Open hearth charging	14′ 0″	
1	7½	3½	...	Yes	...	...	Yes	...	...	d-c.	4	Electric overhead traveling	59′11½″	Bronze axles
1	10	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Mill	47′11″	
1	10	..	...	Yes	...	...	Yes	...	...	d-c.	2	Trolley only	6′ 6″	Trolley
1	10	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Mill	44′ 0″	
3	10	..	...	...	Yes	...	Yes	...	...	d-c.	3	Mill	68′ 0″	
1	10	10	Yes	...	...	Yes	...	...	...	230 d-c.	4	Magnet handling	44′10″	Also helical gears
1	10	..	Yes	...	...	...	Yes	...	...	d-c.	2	Trolley only	.....	Trolley
1	10	..	...	Yes	...	...	Yes	...	...	230 d-c.	4	Magnet and bucket handling	88′ 4″	
1	10	..	...	Yes	...	...	Yes	...	...	230 d-c.	2	Bridge only	22′ 8″	Bridge
1	10	..	Yes	...	...	...	...	...	...	230 d-c.	2	Trolley only	.....	Trolley
1	10	10	...	Yes	...	Yes	...	...	...	230 d-c.	6	Soaking pit	61′ 0″	
1	10	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Standard	63′10″	
1	10	..	...	...	Yes	...	Yes	...	...	230 d-c.	3	Double hook, two drum	83′10″	
1	10	..	Yes	...	...	...	...	Yes	...	d-c.	3	Electric overhead traveling	48′ 4″	
4	10	..	...	Yes	...	...	Yes	...	...	d-c.	3	Shop	64′ 0″	
1	10	..	Yes	...	...	...	...	...	Yes	d-c.	3	Electric overhead traveling	75′ 0″	
1	10	..	Yes	...	...	...	Yes	...	...	d-c.	3	Electric overhead traveling	102′ 0″	
1	10	..	Yes	...	...	...	Yes	...	...	d-c.	2	Trolley only	.....	Trolley
1	10	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Mill	81′ 0″	
1	10	..	Yes	...	...	...	Yes	...	...	d-c.	3	Electric overhead traveling	86′ 7½″	
1	10	..	Yes	...	...	...	Yes	...	...	d-c.	3	Electric overhead traveling	56′ 0″	
1	10	..	Yes	...	...	...	Yes	...	...	230 d-c.	4	Double hoist crane	97′ 1⅛″	Two 5 ton hoists
1	10	5	Yes	...	...	...	Yes	...	...	d-c.	4	Electric overhead traveling	41′ 9¾″	
1	15	..	...	Yes	...	...	Yes	...	...	d-c.	3	Shop	57′11″	
3	15	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Mill	84′ 0″	
1	15	..	Yes	...	...	...	Yes	...	...	d-c.	2	Rail hoist	50′ 0″	
1	15	..	Yes	...	...	Yes	...	...	...	230 d-c.	6	Soaking pit	80′ 0″	
1	15	..	Yes	...	...	...	Yes	...	...	d-c.	5	Pit	85′ 9″	
1	15	..	...	...	Yes	...	Yes	...	...	d-c.	2	Shop (trolley only)	8′ 0″	Trolley
5	15	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Standard	57′ 1″	
1	15	..	Yes	...	...	...	Yes	...	...	d-c.	1	Mill	61′ 2″	Bridge only
2	15	..	Yes	...	...	Yes	...	...	...	230 d-c.	6	Soaking pit cranes	80′ 0″	
1	15	..	Yes	...	...	...	Bridge	Yes	...	d-c.	2	Hand-powered bridge, two motor trolley	29′ 0″	
1	15	..	Yes	...	...	...	Yes	...	...	a-c.	3	Electric overhead traveling	27′ 1¼″	
1	15	..	Yes	...	...	...	...	Yes	...	d-c.	3	Mill	80′ 0″	
2	15	..	Yes	...	...	...	Yes	...	...	d-c.	4	Standard overhead	100′ 0″	
1	20	..	...	...	Yes	...	...	...	...	d-c.	3	Shop	68′ 0″	
1	20	..	...	Yes	...	...	Yes	...	...	d-c.	3	Mill	49′ 6″	
1	20	..	Yes	...	...	...	Yes	...	...	d-c.	4	Mill	102′ 0″	
1	25	7½	Yes	...	...	...	Yes	...	...	d-c.	4	Mill	60′ 6″	
2	25	10	Yes	...	...	...	Yes	...	...	d-c.	4	Mill	74′ 0″	
1	25	..	Yes	...	...	...	Yes	...	...	d-c.	6	Mill	85′ 0″	Bucket and magnet
1	25	..	...	Yes	...	...	Yes	...	...	d-c.	3	Mill	55′ 6″	
1	25	..	Yes	...	...	...	Yes	...	...	d-c.	5	Mill	95′ 6″	
1	25	10	Yes	...	...	...	...	Yes	...	d-c.	5	Electric overhead traveling	87′ 0″	
1	25	..	...	Yes	...	...	Yes	...	...	d-c.	3	Mill	56′ 0″	
2	25	..	Yes	...	...	Yes	...	Bridge	...	d-c.	4	Electric overhead traveling	87′ 0″	
1	25	..	...	Yes	...	...	Yes	...	...	d-c.	4	Mill	80′ 0″	
1	25	..	...	Yes	...	...	Yes	...	...	d-c.	3	Mill	35′ 6″	
1	25	10	Yes	...	...	...	Yes	...	...	a-c.	4	Standard overhead	70′ 0″	
1	25	10	Yes	...	...	...	Yes	...	...	d-c.	4	Electric overhead traveling	100′ 0″	
1	25	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Double trolley crane	108′ 6″	
1	30	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Mill type	40′ 0″	
1	30	10	...	...	Yes	...	Yes	...	...	220 d-c.	3	Auxiliary trolley for ladle crane	.....	Trolley
1	30	10	...	Yes	Yes	...	Yes	...	...	d-c.	5	Tower	30′ 0″	
1	30	..	Yes	...	...	...	Yes	...	...	a-c.	2	Trolley only	8′ 0″	Trolley
2	35	5	Yes	...	...	...	Yes	...	...	d-c.	4	Electric overhead traveling	51′ 4¾″	
1	35	..	Yes	...	...	...	...	...	...	d-c.	1	Bridge only	80′ 8″	Bridge equipped with 7½° helical gears
1	35	10	Yes	...	...	...	Yes	...	...	d-c.	4	Mill	75′ 0″	
1	35	10	Yes	...	...	...	Yes	...	...	d-c.	5	Electric overhead traveling	100′ 0″	
1	35	..	Yes	...	...	...	Yes	...	...	d-c.	3	Mill	88′ 4″	
1	40	10	Yes	...	...	...	Yes	...	...	d-c.	4	Electric overhead traveling	66′ 0″	
1	45	10	...	...	Yes	...	Yes	...	...	230 d-c.	5	Double trolley crane	63′10″	
1	40	..	Yes	...	...	...	Yes	...	...	230 d-c.	3	Mill type	81′ 0″	
1	50	15	Yes	...	...	...	Yes	...	...	230 d-c.	4	Mill type	60′ 0″	
1	50	10	...	...	Yes	...	Yes	...	...	d-c.	4	Shop	67′ 0″	
1	50	15	...	Yes	...	...	Yes	...	...	a-c.	4	Shop	85′ 0″	
1	50	10	...	...	Yes	...	Yes	...	...	d-c.	4	Shop	56′ 0″	
1	50	5	...	...	Yes	...	Yes	...	...	d-c.	6	Shop	73′ 3½″	
1	60	..	...	...	Yes	...	Yes	...	...	220 d-c.	3	Ladle trolley	.....	Trolley
1	60	15	Yes	...	...	...	Yes	...	...	d-c.	5	Mill	80′ 0″	
1	60	15	Yes	...	...	...	Yes	...	...	d-c.	5	Mill	120′ 0″	
1	60	25	...	Yes	...	...	Yes	...	...	d-c.	5	Electric overhead traveling	76′ 2″	Bronze axles
2	60	60	Yes	...	...	...	Yes	...	...	d-c.	4	Smelter	60′ 0″	
1	60	20	Yes	...	...	...	Yes	...	...	d-c.	4	Standard overhead	60′ 0″	
2	75	..	...	Yes	...	...	Yes	...	...	d-c.	4	Shipyard	161′ 4″	
1	75	25	Yes	...	...	...	Yes	...	...	d-c.	7	Ladle	55′ 4″	
1	75	..	Yes	...	...	...	Yes	...	...	230 d-c.	6	Ladle	70′ 3½″	
1	75	25	...	...	Yes	...	Yes	...	...	d-c.	5	Shop	90′ 0″	
1	100	15	...	...	Yes	...	Yes	...	...	d-c.	4	Powerhouse	82′ 0″	
1	100	..	Yes	...	...	...	Yes	...	...	d-c.	3	Ordnance	76′ 0″	
1	100	17½	...	...	Yes	...	Yes	...	...	230 d-c.	6	Ladle	58′ 8″	
2	100	25	Yes	...	...	...	Yes	...	...	d-c.	7	Ladle	70′ 0″	
1	100	10	...	...	Yes	...	Yes	...	...	a-c.	3	Powerhouse (trolley only)	13′ 0″	Trolley
1	100	15	Yes	...	...	...	Yes	...	...	d-c.	...	Ordnance	65′ 0″	
1	120	..	...	Yes	...	...	Yes	...	...	230 d-c.	5	Double trolley	66′ 0″	Trolley
1	125	30	Yes	...	...	...	Yes	...	...	d-c.	7	Ladle	70′ 0″	
1	125	25	Yes	...	...	Yes	...	...	...	d-c.	8	Ladle	78′ 0″	
2	125	10	...	...	Yes	...	Yes	...	...	d-c.	6	Shop	56′ 0″	
3	150	25	...	Yes	...	...	Yes	...	...	d-c.	4	Standard overhead	100′ 0″	
1	150	15	Yes	...	...	...	Yes	...	...	d-c.	5	Ordnance	65′ 0″	
2	150	..	...	Yes	...	...	Yes	...	...	d-c.	4	Shipyard	161′ 4″	
2	175	..	...	Yes	...	...	Yes	...	...	d-c.	2	Shop (bridge only)	100′11″	Bridge
1	200	15	...	Yes	...	...	...	...	...	d-c.	7	Stripper	55′ 0″	
1	210	40/15	Yes	...	...	Yes	...	...	...	d-c.	8	Ladle	50′ 4″	
3	225	50/25	Yes	...	...	Yes	...	...	...	230 d-c.	8	4 girder double trolley ladle	58′ 9″	

Summation of Cranes, Trolleys and Bridges Purchased in 1940

Total cranes purchased	132
Total trolleys purchased	10
Total bridges purchased	5
Cranes completely equipped with anti-friction bearings	87
Cranes partially equipped with anti-friction bearings	29
Cranes equipped with plain bearings	18
Trolleys completely equipped with anti-friction bearings	4
Trolleys partially equipped with anti-friction bearings	2
Trolleys equipped with plain bearings	5
Bridges completely equipped with anti-friction bearings	2
Bridges partially equipped with anti-friction bearings	2
Bridges equipped with plain bearings	0
Cranes equipped with spur gears	104
Cranes equipped with spur and worm gears	20
Cranes equipped with spur and helical gears	5
Cranes equipped with spur and herringbone gears	1
Trolleys equipped with spur gears	10
Trolleys equipped with spur and worm gears	0
Trolleys equipped with spur and helical gears	0
Trolleys equipped with spur and herringbone gears	0
Bridges equipped with spur gears	3
Bridges equipped with spur and worm gears	0
Bridges equipped with spur and helical gears	0
Bridges equipped with spur and herringbone gears	0
Total tonnage of cranes, trolleys and bridges purchased	6295
Total motors purchased	577
Cranes, trolleys and bridges using direct-current	572
Cranes, trolleys and bridges using alternating current	5
Cranes, trolleys and bridges, hand-operated (Bridge)	1

placed on the market recently, in 200 and 300 ampere sizes. One diesel-powered unit is provided with a gasoline engine for starting, rather than the conventional motor and batteries.

New methods of arc control contribute materially in the production of welds of high quality. One method of control makes possible the adjustment of both arc heat and arc penetration in a continuous sequence of fine increments, broadening the range and utility of the machine and adding greatly to simplicity of operation.

In the welding electrode field, the usual progress is seen. One new type is a heavy coated rod designed especially for use with low, open circuit voltage, transformer type welders. This electrode, in a complete range of size, may be used for flat, vertical or overhead welding of mild steel. Another development is a coated rod designed for deep groove welding, for positioned and horizontal fillet welds, cover beads, and other down hand work. A number of alloy rods were also announced, including a bare steel electrode for welding and surfacing 11–14 per cent manganese steel parts, shielded arc electrodes for welding very high nickel alloys and stainless steels, and coated electrodes for hard-facing worn parts of straight carbon and manganese steels with layers of 45–59 Rockwell C hardness.

The ever-broadening use of welding in construction and fabrication work has opened up a wide field for the use of welding stands and positioners. Such units can be tilted through a wide angle from the horizontal, and the table can be revolved through a full circle, regardless of angle of tilt. Special jigs or fixtures may be used in place of the table. Units of this type can be either manually or motor operated.

Increasing interest is being shown by steel mills and other plants in the welding of crane runway rails for heavy cranes. The advantages gained by doing away with joints in such rails are more or less obvious, including smoother crane operation, saving in damage to crane and crane structures, elimination of broken wheels, and reduction in maintenance of the runway rail itself. Also, in the case of collector rail, 100 per cent electrical conductivity is obtained.

As an instance of the damage that can be done to crane structures by rail joints, it was found in certain cases that the top legs of the supporting beam on which rail bases rested had been nearly cut in two at each joint. This excessive wear came from the fact that when heavy cranes made sudden stops, they tended to shove the rails forward and down, causing the rail bases at the ends to cut into the beam. With rails welded in continuous lengths the full distance of the runway, this trouble is avoided.

Machines for forming and welding tubular products have been improved considerably. Extremely close control of the forming operation is effected by elimination of the adjusting spindle, which provided for vertical alignment of top and bottom rolls with one another, and also alignment for each complete pass of rolls with the others. Machines of this type make resistance welded tubes in diameters ranging ¼ to 26 in.

The steadily increasing size of welding machines has introduced the problem of power supply to welders. To reduce the kva. demand of these machines and minimize line disturbances, a series-capacitor system has been developed, consisting of a capacitor connected in series with the transformer primary of the resistance welder. Power factor is thus improved, and demand reduced 50–70 per cent. This equipment can be applied to spot, projection, seam, and butt resistance welders, either new or already existing. A late development is the incorporation of a capacitor within the welding unit, making an integral high power factor welder.

ELECTRIC MOTORS OVER 300 HORSEPOWER

Applied to Main Roll Drives in the Iron and Steel and Allied Industries during the year 1940

No.	Horse-power	Revolutions per minute	Volts	Frequency	Method of drive	Kind of mill	Purchaser	Location	Manufacturer
1	300	300/1200	600	d-c.	Geared	29 in. reversing cold mill	Sharon Steel Corporation	Sharon, Pennsylvania	General Electric
2	300	300/1200	600	d-c.	Geared	29 in. reversing cold mill	Sharon Steel Corporation	Sharon, Pennsylvania	General Electric
3	300*	750	440	50	Geared	Brass mill	F. H. Crawford and Company, Inc.	South Africa	General Electric
4	300*	750	220	25	Geared	12 in. merchant mill	Bethlehem Steel Company	Lackawanna, New York	General Electric
5	300	600/1000	600	d-c.	Geared	42 in., 1-stand, temper pass mill, reel	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
6	300	600/1000	600	d-c.	Geared	42 in., 1-stand, temper pass mill, reel	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
7	300	300/600	600	d-c.	Geared	42 in., tandem, temper pass mill	Tennessee Coal, Iron and R.R. Company	Fairfield, Alabama	Allis-Chalmers
8	350	600/1200	250	d-c.	Geared	4-high cold strip brass mill	Anaconda American Brass, Ltd.	New Toronto, Ontario, Canada	General Electric
9	350	250/875	740	d-c.	Geared	75 in. cold strip mill	Bethlehem Steel Company	Lackawanna, New York	Westinghouse
10	400†	600	440	60	Geared	3-high, aluminum breakdown mill	Reynolds Metal Company	Richmond, Virginia	General Electric
11	400	300/1200	600	d-c.	Geared	28 in. reversing cold strip mill	Dominion Foundries and Steel, Ltd.	Hamilton, Ontario, Canada	General Electric
12	400	300/1200	600	d-c.	Geared	28 in. reversing cold strip mill	Dominion Foundries and Steel, Ltd.	Hamilton, Ontario, Canada	General Electric
13	400	350/1050	600	d-c.	Geared	Tandem cold mill	Acme Steel Company	Riverdale, Illinois	Westinghouse
14	500	250/875	600	d-c.	Geared	42 in. reversing cold strip mill	Allegheny-Ludlum Steel Corporation	West Leechburg, Pennsylvania	General Electric
15	500	250/875	600	d-c.	Geared	42 in. reversing cold strip mill	Allegheny-Ludlum Steel Corporation	West Leechburg, Pennsylvania	General Electric
16	500	300/1050	600	d-c.	Geared	Tandem cold mill	Acme Steel Company	Riverdale, Illinois	Westinghouse
17	500‡	1160	2200	60	Geared	Tube mill	Babcock and Wilcox Tube Company	Beaver Falls, Pennsylvania	Westinghouse
18	500‡	1160	2200	60	Geared	Tube mill	Babcock and Wilcox Tube Company	Beaver Falls, Pennsylvania	Westinghouse
19	500	370/1300	600	d-c.	Geared	42 in. skin pass mill	Weirton Steel Company	Weirton, West Virginia	Westinghouse
20	500	250/375	600	d-c.	Geared	42 in. skin pass mill	Weirton Steel Company	Weirton, West Virginia	Westinghouse
21	500	350/650	600	d-c.	Geared	48 in. temper pass mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	Allis-Chalmers
22	500	350/620	600	d-c.	Geared	42 in. temper pass mill	Tennessee Coal, Iron and R.R. Company	Fairfield, Alabama	Allis-Chalmers
23	500	400/600	316	d-c.	Geared	42 in. tandem mill	Tennessee Coal, Iron and R.R. Company	Fairfield, Alabama	Allis-Chalmers
24	500	400/600	316	d-c.	Geared	42 in. tandem mill	Tennessee Coal, Iron and R.R. Company	Fairfield, Alabama	Allis-Chalmers
25	600	200/800	750	d-c.	Geared	Cold strip mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	General Electric
26	600	225/787	600	d-c.	Geared	Reel	Societe du Duralumin	France	General Electric
27	600	200/800	600	d-c.	Geared	54 in. cold strip mill	Republic Steel Corporation	Cleveland, Ohio	Westinghouse
28	600	600/960	250	d-c.	Geared	Reversing cold strip mill	Broken Hill Proprietary Company	Sidney, Australia	Westinghouse
29	600	200/700	600	d-c.	Geared	54 in. cold strip reel	American Rolling Mill Company	Middletown, Ohio	Westinghouse
30	600	350/500	600	d-c.	Direct	42 in. 1-stand, temper pass mill	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
31	750	400/800	600	d-c.	Geared	34 in. reversing cold mill	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
32	750	400/800	600	d-c.	Geared	34 in. reversing cold mill	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
33	750	400/800	600	d-c.	Geared	34 in. reversing cold mill	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
34	750	400/800	600	d-c.	Geared	34 in. reversing cold mill	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
35	800	300/750	750	d-c.	Geared	Cold strip mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	General Electric
36	800*	400	2300	60	Geared	Aluminum sheet mill	Aluminum Company of America	Edgewater, New Jersey	Westinghouse
37	800‡	300	2300	60	Geared	Aluminum sheet mill	Aluminum Company of America	Edgewater, New Jersey	Westinghouse
38	800	250/550	300	d-c.	Geared	Cold sheet mill	Dow Chemical Company	Midland, Michigan	Westinghouse
39	800	640/1020	600	d-c.	Geared	24 in. reversing cold strip mill	Bopp Steel Company	Detroit, Michigan	Westinghouse
40	800+	0/37/80	500	d-c.	Direct	Blooming mill	Universal-Cyclops Steel Corporation	Bridgeville, Pennsylvania	Allis-Chalmers
41	800	350/575	600	d-c.	Geared	48 in. temper pass mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	Allis-Chalmers
42	800	315/515	600	d-c.	Geared	48 in. temper pass mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	Allis-Chalmers
43	800	250/600	600	d-c.	Geared	42 in. tandem temper pass mill	Tennessee Coal, Iron and R.R. Company	Fairfield, Alabama	Allis-Chalmers
44	800	250/600	600	d-c.	Geared	42 in. tandem temper pass mill	Tennessee Coal, Iron and R.R. Company	Fairfield, Alabama	Allis-Chalmers
45	900	450/0/450	600	d-c.	Geared	Reversing mill	American Brass Company	Detroit, Michigan	Westinghouse
46	1000‡	514	2300	60	Geared	Aluminum rod mill	Aluminum Company of America	Massena, New York	General Electric
47	1000	350/835	600	d-c.	Direct	Tandem cold mill	Republic Steel Corporation	Warren, Ohio	General Electric
48	1000	400/800	600	d-c.	Geared	Cold strip mill	American Rolling Mill Company	Butler, Pennsylvania	General Electric
49	1000*	300	4600	60	Geared	Brass mill	American Brass Company	Detroit, Michigan	General Electric
50	1000	325/800	600	d-c.	Geared	Cold reversing mill for duralumin	Mitsui and Company	Japan	General Electric
51	1000	150	600	d-c.	Geared	Wheel mill	Tata Iron and Steel Company	India	General Electric
52	1000	250/750	600	d-c.	Geared	Steckel mill	American Steel and Wire Company	Cleveland, Ohio	Crocker-Wheeler
53	1250*	720	4600	60	Geared	14 in. merchant mill	Allegheny-Ludlum Steel Corporation	Dunkirk, New York	General Electric
54	1250	200/500	600	d.c.	Direct	Tandem cold mill	Republic Steel Corporation	Warren, Ohio	General Electric
55	1250	500/750	600	d-c.	Geared	No. 2 rod mill	Bethlehem Steel Company	Sparrows Point, Maryland	General Electric
56	1250	275/550	600	d-c.	Geared	28 in. reversing cold strip mill	Dominion Foundries and Steel, Ltd.	Hamilton, Ontario, Canada	General Electric
57	1250	600/800	600	d-c.	.....	Cold strip mill	Wheeling Steel Corporation	Yorkville, Ohio	Crocker-Wheele
58	1500	300/600	600	d-c.	Geared	Aluminum hot strip mill	Aluminum Company of America	Alcoa, Tennessee	General Electric
59	1500	300/600	600	d-c.	Geared	42 in. reversing cold strip mill	Allegheny-Ludlum Steel Corporation	West Leechburg, Pennsylvania	General Electric
60	1500	325/650	600	d.c.	Direct	Tandem cold mill	Republic Steel Corporation	Warren, Ohio	General Electric
61	1500	300/500	600	d-c.	Direct	34 in. cold reversing mills	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
62	1500	300/500	600	d-c.	Direct	34 in. cold reversing mills	Follansbee Steel Corporation	Follansbee, West Virginia	Allis-Chalmers
63	1700	300/600	600	d-c.	Geared	75 in. cold tandem strip mill	Bethlehem Steel Company	Lackawanna, New York	Westinghouse
64	1750	60/150	550	d-c.	Direct	42 in. reversing billet mill	Atlas Steel, Ltd.	Welland, Ontario, Canada	General Electric
65	2000	100/250	750	d-c.	Direct	Cold strip mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	General Electric
66	2000	225/525	750	d-c.	Geared	54 in. cold strip mill	American Rolling Mill Company	Middletown, Ohio	Westinghouse
67	2000	225/450	750	d-c.	Direct	54 in. cold strip mill	American Rolling Mill Company	Middletown, Ohio	Westinghouse
68	2000	175/438	600	d-c.	Geared	72 in. 2-stand tandem cold mill	Aluminum Company of America	Alcoa, Tennessee	Allis-Chalmers
69	2250	250/550	600	d-c.	Geared	66 in. 4-high tandem cold mill	Societe du Duralumin	France	General Electric
70	2250	250/550	600	d-c.	Geared	66 in. 4-high tandem cold mill	Societe du Duralumin	France	General Electric
71	2250	250/550	600	d-c.	Geared	66 in. 4-high tandem cold mill	Societe du Duralumin	France	General Electric
72	2500	175/350	750	d-c.	Direct	Cold strip mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	General Electric
73	2500	275/550	750	d-c.	Direct	Cold strip mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	General Electric
74	2500	250/625	750	d-c.	Geared	54 in. cold strip mill	Republic Steel Corporation	Cleveland, Ohio	Westinghouse
75	2500	134/268	750	d-c.	Direct	54 in. cold strip mill	Republic Steel Corporation	Cleveland, Ohio	Westinghouse
76	2500	181/362	750	d-c.	Direct	54 in. cold strip mill	Republic Steel Corporation	Cleveland, Ohio	Westinghouse
77	2500	200/500	750	d-c.	Direct	54 in. cold strip mill	Republic Steel Corporation	Cleveland, Ohio	Westinghouse
78	2500	150/300	750	d-c.	Direct	54 in. cold strip mill	American Rolling Mill Company	Middletown, Ohio	Westinghouse
79	2500	200/400	750	d-c.	Direct	54 in. cold strip mill	American Rolling Mill Company	Middletown, Ohio	Westinghouse
80	3000	400/700	750	d-c.	Direct	Cold strip mill	Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	General Electric
81	3000	30/60	600	d-c.	Direct	Reversing plate mill	Aluminum Company of America	Alcoa, Tennessee	Westinghouse
82	3500	175/350	600	d-c.	Geared	Aluminum hot strip mill	Aluminum Company of America	Alcoa, Tennessee	General Electric
83	3500	175/350	600	d-c.	Geared	Aluminum hot strip mill	Aluminum Company of America	Alcoa, Tennessee	General Electric
84	3500	40/80	600	d-c.	Direct	Reversing 2-high mill	Societe du Duralumin	France	General Electric
85	4000	175/350	600	d-c.	Geared	Aluminum hot strip mill	Aluminum Company of America	Alcoa, Tennessee	General Electric
86	4000	175/350	600	d-c.	Geared	Aluminum hot strip mill	Aluminum Company of America	Alcoa, Tennessee	General Electric
87	5000	30/60	525	d-c.	Direct	Reversing plate mill	Aluminum Company of America	Alcoa, Tennessee	Westinghouse
88	5000	30/60	525	d-c.	Direct	Reversing plate mill	Aluminum Company of America	Alcoa, Tennessee	Westinghouse
	118,850								

*Wound rotor induction motor †Synchronous motor ‡Squirrel cage induction motor +Reversing motors

STATISTICS OF ELECTRIC MOTORS OVER THREE HUNDRED HP

SOLD FOR MAIN ROLL DRIVE SERVICE IN THE IRON AND STEEL INDUSTRY IN 1940

APPLICATIONS OF MOTORS TO VARIOUS TYPES OF MILLS

Type of mill	*Number of mills*	*Number of motors*	*Total horsepower*
24 in. reversing cold strip mill	1	1	800
28 in. reversing cold strip mill	1	3	2,050
29 in. reversing cold mill	1	2	600
34 in. reversing cold mill	1	6	6,000
42 in. 1-stand temper pass mill	1	4	1,700
42 in. tandem temper pass mill	1	1	300
42 in. skin pass mill	1	2	1,000
42 in. reversing cold strip mill	1	3	2,500
42 in. tandem temper pass mill	1	2	1,600
42 in. tandem mill	1	2	1,000
48 in. temper pass mill	1	3	2,100
54 in. cold strip mill	2	10	20,200
72 in. 2-stand tandem cold mill	1	1	2,000
75 in. cold tandem strip mill	1	2	2,050
Cold strip mill	1	1	1,250
Steckel mill	1	1	1,000
Cold strip mill	1	1	1,000
Cold sheet mill	1	1	800
Reversing cold strip mill	1	1	600
Cold strip mill	1	6	11,400
Tandem cold mill	2	5	4,650
12 in. merchant mill	1	1	300
Blooming mill	1	1	800
Wheel mill	1	1	1,000
14 in. merchant mill	1	1	1,250
42 in. reversing billet mill	1	1	1,750
Tube mill	1	2	1,000
Rod mill	1	1	1,250
Cold reversing mill (aluminum)	1	1	1,000
66 in. 4-high tandem cold mill (aluminum)	1	4	7,350
Hot strip mill (aluminum)	1	5	16,500
Reversing plate mill (aluminum)	1	3	13,000
3-high breakdown mill (aluminum)	1	1	400
Sheet mill (aluminum)	1	2	1,600
Rod mill (aluminum)	1	1	1,000
Reversing 2-high mill (aluminum)	1	1	3,500
4-high cold strip brass mill	1	1	350
Brass mill	1	3	2,200
		85	118,850

Company	*Location*	*Type of mill*	*Number of motors*	*Total horsepower*
Acme Steel Company	Riverdale, Illinois	Tandem cold mill	2	900
Allegheny-Ludlum Steel Corporation	Dunkirk, N. Y.	14 in. merchant mill	1	1,250
	West Leechburg, Pennsylvania	42 in. reversing cold strip mill	3	2,500
Aluminum Company of America	Alcoa, Tennessee	Aluminum hot strip mill	5	16,500
		72 in., 2-stand tandem cold mill	1	2,000
		Reversing plate mill	3	13,000
	Edgewater, N. J.	Aluminum sheet mill	2	1,600
	Massena, N. Y.	Aluminum rod mill	1	1,000
American Brass Company	Detroit, Michigan	Reversing brass mill	1	900
		Brass mill	1	1,000
American Rolling Mill Company	Butler, Pennsylvania	Cold strip mill	1	1,000
	Middletown, Ohio	54 in. cold strip mill	5	9,600
American Steel and Wire Company	Cleveland, Ohio	Steckel mill	1	1,000
Anaconda-American Brass, Ltd.	New Toronto, Ontario, Canada	4-high cold strip brass mill	1	350
Atlas Steel, Ltd.	Welland, Ontario, Canada	42 in. reversing billet mill	1	1,750
Babcock and Wilcox Tube Company	Beaver Falls, Pennsylvania	Tube mill	2	1,000
Bethlehem Steel Company	Lackawanna, New York	12 in. merchant mill	1	300
		75 in. cold strip mill	2	2,050
	Sparrows Point, Maryland	No. 2 rod mill	1	1,250
Bopp Steel Company	Detroit, Michigan	24 in. reversing cold strip mill	1	800
Broken Hill Proprietary Company, Ltd.	Sidney, Australia	Reversing cold strip mill	1	600
Carnegie-Illinois Steel Corporation	Dravosburg, Pennsylvania	48 in. temper pass mill	3	2,100
		Cold strip mill	6	11,400
F. H. Crawford and Company, Inc.	South Africa	Brass mill	1	300
Dominion Foundries and Steel, Ltd.	Hamilton, Ontario, Canada	28 in. reversing cold strip mill	3	2,050
Dow Chemical Company	Midland, Michigan	Cold sheet mill	1	800
Follansbee Steel Corporation	Follansbee, West Virginia	42 in., 1-stand temper pass mill	3	1,200
		34 in. reversing cold mill	6	6,000
Mitsui and Company	Japan	Cold reversing mill for duralumin	1	1,000
Republic Steel Corporation	Cleveland, Ohio	54 in. cold strip mill	5	10,600
	Warren, Ohio	Tandem Cold Mill	3	3,750
Reynolds Metal Company	Richmond, Virginia	3-high aluminum breakdown mill	1	400
Sharon Steel Corporation	Sharon, Pennsylvania	29 in. reversing cold mill	2	600
Societe du Duralumin	France	66 in. 4-high tandem cold mill	3	6,750
		Reel	1	600
		Reversing 2-high mill	1	3,500
Tata Iron and Steel Company	India	Wheel mill	1	1,000
Tennessee Coal, Iron and R. R. Company	Fairfield, Alabama	42 in. tandem temper pass mill	6	3,400
Universal-Cyclops Steel Corporation	Bridgeville, Pennsylvania	Blooming mill	1	800
Weirton Steel Company	Weirton, West Virginia	42 in. skin pass mill	2	1,000
Wheeling Steel Corporation	Yorkville, Ohio	Cold strip mill	1	1,250

Types of motors purchased	*Total motors*	*Total horsepower*
Alternating current motors	13	6,850
Direct current motors	72	112,000
		118,850

STEEL PLANT
Maintenance Shops

By T. R. MOXLEY
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PRESENTED BEFORE A. I. S. E. ANNUAL CONVENTION, CHICAGO, ILLINOIS, SEPTEMBER 24-27, 1940

▲ THE preparation of this paper has presented an opportunity for expression on a subject that has been, more or less, a personal hobby ever since the early days of my apprenticeship—contending that a plant maintenance department is no more efficient than the provisions made for shop equipment and personnel, as herein lies the controlling factor in the final analysis of the cost sheet.

In construction of new plants and the expansion and modernization of older plants, this fact should be borne in mind if satisfactory maintenance costs are to be realized. The modern steel mill of today is a machine in which the maximum of engineering skill is applied. The shop in which the machine is built must necessarily be, and is equipped with the most modern machine tools, foundry and laboratory equipment of the latest design, together with research laboratories operated by and managed with the highest type of mechanical skill available. This is the competition with which the maintenance superintendent is confronted in his efforts to maintain this masterpiece of engineering, and unless the plant shops are equipped comparably with those of the manufacturer, excessive cost will result..

T. R. MOXLEY

Assuming the above as a matter of fact, it is necessary to establish a basis for the consideration of plant maintenance shops such as:

1. Investment.
2. Necessary equipment.
3. Geographical location.
4. Arrangement of equipment to conserve floor space and facilitate progressive movement of material through the shop to avoid as much as possible back-tracking.

From the standpoint of investment, this would, naturally, be a matter of company policy. Considering the matter of purchasing materials from outside manufacturers as compared to the manufacture of materials in the plant shops, not all steel plants are located in close proximity to manufacturing shops; therefore, it is imperative that a large portion of maintenance items be manufactured in the plant shops, also when purchasing material from outside concerns, spare equipment requirements must be anticipated very closely. In order to avoid excessive investment in spare parts and to insure delivery of material when or before it is needed, this factor alone suggests that a steel plant with a well-equipped shops department is more or less independent and the investment in spare materials can be reduced to a minimum. For obvious reasons, such as profit, freight, overhead, engineering, it is economical to produce within the plant rather than purchase from outside concerns. This is an outstanding factor in reaching the objective of reduced maintenance cost per ton, and I will venture to say the savings on labor alone will average approximately 42 per cent. In regard to necessary equipment, this will be presented for each shop individually.

The geographical location of the plant shops department should be as near as possible centrally located in order to serve the greatest number of production departments, readily accessible through transportation facilities, such as railroads, trucks, etc. The arrangement of equipment and shop buildings is a matter of plant

engineering. Shop buildings should be so located that material from the foundry and forge shop can be delivered to what may be termed casting and forging yard, which should be adjacent to the machine shop, this yard to be served by a gantry crane with transfer car to transport castings and forgings into the machine shop, for machining as per schedule. This will provide a more orderly operation in the machine shop and greatly avoid congestion, as there are many machine shops in which material must be placed due to lack of such accommodations. It would be found advantageous to house the boiler and structural shop and welding shop in the same building as the progress made by the science of welding in the fabrication of structural steel and plate work has been rapid and will continue to be.

All steel plants must maintain rolling stock such as steam and diesel locomotives, locomotive cranes and railroad cars. In order to take care of maintenance on locomotives and locomotive cranes, provision should be made in one end of the general machine shop for this purpose, as locomotive rebuilds and running repairs require considerable machine work. With a set-up of this kind it would not be necessary to equip a locomotive shop with machine tools that is located at some isolated point away from the machine shop.

SHOP BUILDINGS

The shops department should consist of pattern shop, foundry, forge shop, boiler and structural shop, welding shop, carpenter shop, pipe shop, and rigging shop, as well as the combination machine and locomotive shop mentioned above. This, within itself, constitutes a department, that when properly operated should be managed by a superintendent of shops, through whom all maintenance material is requisitioned, whether it is to be manufactured locally or purchased from an outside manufacturer. This procedure would afford the shop superintendent with a general knowledge of maintenance material requirements, thereby aiding him in his decisions as to whether economies could be effected by the manufacture of material locally or to purchase from outside concerns, as in a great many cases material purchased on the outside would be governed according to the shop equipment available.

Shop buildings should be of ample proportions and should be built with the consideration for future expansion, and of such design as to provide the maximum of daylight, and fluorescent lighting preferably for night work. A controlled heating system should be installed, which will afford uniform heat during all seasons of the year. The unit heating system has proven very satisfactory for this service as the unit can be placed in locations that will provide uniform distribution; also during the summer season the fan contained within the heater is equipped for air circulation or cooling. Most shops are constructed with a main center aisle, and a lean-to on either side, the larger machines for the heavy class of work, as well as the erecting floor being located in the center aisle and the smaller machines for the lighter class of work, work benches, etc., located in the lean-tos. Buildings should be equipped with the necessary overhead cranes of sufficient capacity to handle the class of work required of each shop.

Each shop building should be provided with a service building and locker room for the convenience of employees. This will be found a most profitable investment as desirable surroundings and conveniences such as these are conducive to creating interest and a genuine desire on the part of the employee in performing his duties dependably.

MACHINE SHOP

The machine shop is considered the most important of the group and should be serviced by two overhead electric cranes over the center aisle, one to be of not less than 75-ton capacity and the other 25-ton. Much valuable time is wasted in shops of insufficient crane capacity. Monorail cranes, as well as jib cranes, air or electric hoists have proven very satisfactory for the lean-to sections, and where the smaller machines and work benches would be installed. The shop tool room cannot be over-emphasized as upon this department the efficient operation of all units depends. The tool room must be of ample size for proper care and maintenance of tools, jigs, templates, etc., and be equipped with machines for the maintenance and manufacture of small tool requirements as are needed not only in the machine shop but other shops as well. Machine shop tool room equipment usually consists of precision lathes, small milling machines, grinders for cylindrical and surface grinding, and those grinders of a special nature for grinding milling and gear cutters, dies, drills, reamers, cemented carbide tools, etc., a small shaper and drill press. For the shop where the production of templates is important, such as rail and structural mills, a small combination punch press and shear and metal band saw can also be used advantageously.

A card index system, similar to those used in general store rooms, to be a complete record of all tools will be found indispensable for accounting purposes as related to tool costs and for replacement of worn-out and broken tools. A system that will insure the return of tools to the tool room must be provided. There are many such systems; however, I think the check system is generally accepted and seems to meet with popular favor in most shops. By this method, a check is issued for the item received from the tool room and is taken up when the tool is returned. The matter of arrangement of bins and lockers for the proper care of tools is one of space and convenience.

The selection of machine tools for the steel plant machine shop depends upon the amount and the nature of plant equipment. Strip mill maintenance differs somewhat from that of the heavy structural and plate mills, therefore, shop tools are selected accordingly. The equipment following would constitute that necessary for the average steel plant machine shop:

Vertical boring mills will range from 4 to 16 ft.; horizontal boring mills, sizes of which are usually considered by size of the spindle, from 3 in. spindle and table of comparable size, high speed for small work, to 6 in. spindle with corresponding table for large work, both spindles and tables of variable speeds and feeds in horizontal and vertical direction with rapid traverse.

One of the most useful machines in a steel plant shop is the combination draw-cut planer and post mill. This

machine is considered ideal as its performance embodies all operations of other machines except turning, and can be considered the utility machine of the shop. The size of this machine, generally accepted for plant use is 12 in. draw-cut rail, 6 in. boring spindle with an auxiliary smaller spindle for high speed boring and drilling, vertical head travel 8 ft., horizontal head travel 12 ft., floor plate 14 ft. square with auxiliary table for small work. The great advantage of this machine is realized in the time saved in setting up work, as usually all operations can be done with one setting. This machine, operated by experienced operators, will pay larger dividends than any other machine in the shop.

Lathes ranging from 60 in. x 40 ft. bed, down to 16 in. x 4 ft. bed, all of heavy duty construction, are standard equipment. The number of the various size lathes depends on the class and quantity of work to be done. The most popular sizes in most shops are between 36 and 20 in. A plant shop would not be complete without at least one 24 in. turret lathe, this being a production machine, indispensable for machining duplicate parts.

A plant maintenance shop seldom requires a planer larger than 10 ft. between housings and under the rail, with table from 20 to 26 ft. Work requiring a larger machine is of such small percentage that investment in a larger machine of this type would not be justified. Planers of smaller sizes, down to 3 ft. between the housings and under the rail with approximately 10 ft. table, will be found satisfactory for the smaller class of work. The shaper is employed in sizes from 36 to 18 in. Another planing machine of importance, of which every plant shop should have at least two, is the slotter for vertical planing. The popular sizes of this machine are from 36 to 72 in. The universal milling machine, as they are manufactured today, implies what the name suggests—they are indeed universal. The performance of this machine embodies practically all operations necessary for the completion of a machine part, except turning, from flat milling to cutting the teeth of spiral or bevel gears, and is in reality a production unit, very efficient and economical in the manufacture of duplicate parts.

The plant shop should have at least one gear hobbing machine. The 48 in. machine seems to be accepted as the correct size, with a capacity for cutting teeth 1½ D.P., 48 in. diameter maximum. This machine will fulfill the maintenance requirements of a large percentage of the plant and will cut spur, helical and spiral gears, worms and worm wheels. It is automatic when once the work is set up and requires very little attention by the operator. For gears of larger diameters it will be found economical to purchase from outside manufacturers, as the investment in a larger machine would not be justified for a maintenance shop.

One bevel gear generator should be provided for the manufacture of bevel gears for line shafts, table rolls, etc. This machine should generate gear teeth of 1 D.P., and 36 in. diameter would be sufficient. The purchase price of a larger machine would be prohibitive for the same reasons as the hobbing machine.

A machine that during the past few years has been favorably accepted by maintenance shops is the grinder for external and internal cylindrical grinding. Modern mill machinery, in which alloy steels and irons, hardened surfaces, precision fits in maintenance of anti-friction bearings, make necessary the employment of this machine; likewise, polishing surfaces, formerly finished in the lathe by the old method of filing, rolling, or the use of emery cloth, is accomplished with greater accuracy and considerable reduction in time, and improvement in quality is realized from this machine, also machining time in the lathe is reduced.

Drill presses of the radial type with 6 ft. arm and 19 in. column, also 4 ft. arm and 12 in. column; two of the larger size and one of the smaller size, will be sufficient for steel plant shops and should be located in the main center aisle with the larger machines. Smaller drill presses of the post type, located in the tool room and lean-tos will be found satisfactory. A keyway miller for milling keyways in shafts, of sufficient capacity for milling a 2 in. keyway, and a keyway slotter for machining keyways in the bore of wheels of the same capacity, one of which would be sufficient.

Pneumatic hand tools, such as chipping hammers, air drills, hand grinders and polishers, used on the assembly floor have eliminated a large part of hand filing and chipping and have greatly improved the efficiency in the assembly of machine parts. In connection with the assembly floor, a hydraulic press of at least 500-ton capacity should be provided for the removal and application of wheels to be fit to shafts, axles, etc.

In regard to the locomotive repair shop, formerly suggested to be a part of one end of the machine shop, the capacity of this shop naturally depends upon the number of locomotives and cranes to be serviced. This department would be equipped with a 75-ton overhead crane and should have at least one drop pit for removal of wheels; also tool room other than the main shop tool room should be provided for this department as a great many special tools pertaining only to locomotive rebuilds and repair work are used in this department. A portable boring bar would be found convenient for remachining the bore in steam chests and cylinders, also proper pneumatic tools and welding machine for boiler repairs are essential.

FORGE SHOP

In considering the building for the forge shop, the same general design as previously mentioned is applicable, with the exception that forced draft ventilators be installed in the roof for removal of heat and escaping furnace gases, when charging or withdrawing heats. Various types and sizes of furnaces are required for producing proper heating capacity, also heat treating furnaces, normalizers, etc. An overhead electric crane of 25-ton capacity, also a jib crane for handling small work, one hydraulic press for heavy forgings, steam or pneumatic hammers for light forgings and tool dressing, forging machine, cold saw and such other equipment as pertains to heat treating, hardening, etc., such as oil and water quenching, salt bath, carburizer, etc.

The hydraulic press should be of 1000 to 1500 tons, with heating furnace, preferably gas fired, hearth size 8 x 12 ft., 3 doors front and back, so located as to permit handling of forgings with the overhead crane. The minimum crew for operation of this equipment would consist of forger, heater, press operator, and two helpers. Steam or pneumatic hammers from 800 to

4000 lb. capacity will be found ample for the light class of forging and tool dressing, with hearth of furnace 4 x 6 ft. of general design as mentioned above. In considering the crew for these smaller units, a forging hammer operator, one helper and apprentice will be sufficient as the nature of this class of forging does not necessitate the services of a heater. The open forge, while gradually having passed into obsolescence, has been replaced with small gas fired furnaces, however, it still plays a part in the dressing of small tools, where only points or cutting edges are to be heated, a small furnace being used by the tool maker when heating steel for forming, heat treating and tempering. Forging machine, threading and tapping machines are usually considered standard equipment in the larger plants for the manufacture of bolts, nuts, rivets, open hearth stopper rods and many other items used in large quantities.

Forging machines of two sizes are usually employed; one machine for ½ to 1½ in., and the other 1½ to 3½ in., are accepted as standard for steel plant service. Threading and tapping machine, ½ to 3 in., of the multiple head type, insure maximum production. Double head shear for shearing rounds, squares and flat bars, located adjacent to the stock rack, saves time and material, also in the larger plants a cold saw for cutting to length the forged shaftings, axles, etc., before shipping to the machine shop reduces machine time and handling of excessive scrap ends.

HEAT TREATING

This department of a steel plant forge shop is of great importance and is becoming more so from day to day, as a large portion of present day machinery consists of alloy steels, the metallurgical properties of which require very accurate and scientific heat treating. These materials, while not altogether new, present problems to the forge shop foreman not heretofore encountered. He is called upon to furnish an alloy that will function properly in a machine of given horsepower, torque load, bending moment, etc. Furnaces of sufficient capacity are designed to accommodate the general line of work. Of first importance, and of necessity, these furnaces must be automatically controlled. Provision should be made for proper quenching and air cooling. Salt bath furnaces also are found advantageous in treating smaller pieces such as milling cutters and tools of this type, as this furnace lends itself to accurate heat control and prevents scaling of part to be treated. This department should be housed apart from but adjacent to the forge shop and operated under the supervision of the forge shop foreman.

BOILER, STRUCTURAL AND RIGGER SHOP

This may be considered the utility shop of the entire group, as the service rendered is of diversified nature. The mechanical maintenance crews in the several operating departments usually consist of a personnel of sufficient number to service the department from the standpoint of running repairs. When repairs of major proportions are necessary the additional man power for work of this nature is usually supplied from this shop, with the exception of pipe work and repairs to precision machinery, the latter by thepipe and machine shops respectively.

Generally speaking, the greater portion of mill repairs, *i.e.*, blast furnaces, open hearth, heavy mill machinery, buildings, soaking pits, crane runways, boilers, etc., will be found in the category of this particular shop; thus the necessity of a well-trained organization in this shop is obvious and will be realized in the efficient performance of this class of maintenance.

The building for this shop should, of necessity, be the largest of the group, as here the maintenance of railroad cars, fabrication of all structural and plate work and welding is done. A comparatively large space is provided for laying out work, and storing materials, as structural sections and plate should not be left exposed to the weather. It is, therefore, imperative that a reasonable stock of this material be carried on inventory, in order to avoid delays in obtaining material, particularly in those plants where it is not manufactured. The building should be of the same general design, well lighted, and amply serviced with overhead cranes, also provision made for proper ventilation and heat.

The equipment for this shop consists of plate and structural shears, plate forming presses, bending rolls for structural shapes and plate, punch presses, riveting machines, drill presses, stationary and portable grinders, heating furnaces adjacent to heavy forming presses, standard gauge railroad tracks for car repairs, hydraulic test pump for use in testing pressure vessel construction. Shears should be of ample capacity for shearing 1 in. plate, 144 in. long maximum, with high speed shear for lighter class of work, same is true of structural shear, with ample capacity of 15 in. beam, ¾ in. web thickness, angle 8 in. x 8 in. x 1 in.; a smaller shear for the lighter sections, punch presses ranging in capacity from ⅜ in. to 2 in. hole and ⅛ in. to 1 in. thickness, with 6 ft. radial drill press for heavier sections and larger diameter holes. Bending rolls, maximum capacity 1 in. plate x 84 in. wide, rolls to be adjustable for forming cone shaped sections. In the forming of concave and convex heads for tank work, it will be found economical to purchase this class of material from tank builders as the percentage of this work is very small in steel plant maintenance. Plate forming presses of a capacity for forming ½ in. cold plate, are necessary in the maintenance of railroad cars and should be located near the repair tracks. It will be found convenient to equip the larger machines in this shop with jib or monorail cranes as it would not be practical to service these machines during the operation of shearing, punching, etc., with the overhead crane as this would result in delays and lost time of other operations. Also, riveting machines are usually mounted on portable jib or monorail cranes in such manner as to provide easy access in the performance of riveting operations. Portable rivet heating furnaces, preferably gas fired, are provided with gas and air connections, conveniently located over the entire shop. An air compressor of ample capacity, equipped with filters, inter-coolers and receiver, is a valuable asset to a structural shop. In order to properly fabricate structural steel, constant and uniform air pressure must be maintained. This is not always possible where the compressed air is furnished from the general service

plant compressors. Pneumatic tools, such as hammers, impact wrenches, grinders, drills, etc., properly maintained are necessary. Here again, the necessity of proper tool room facilities must be emphasized. Facilities for proper application of acetylene torches for machine and hand cutting, also welding, with acetylene generator station, and oxygen furnished from either a generating station or tank battery, distributed throughout the shop through suitable pipe lines are essential for economy as well as efficiency, as the lost time and motion in handling cylinders is eliminated. A small portion of this shop must be assigned to the lighter class of work, commonly known as the tin shop, to be equipped with tools applicable to this work such as shears, bending rolls, crimping machine, etc.; likewise, the importance of the service building must not be neglected.

FOUNDRY

The general construction of this building would be as stated above, except that it is vitally important this building be properly ventilated, especially in the cleaning room, the installation of dust removal equipment being imperative.

The problems of the steel plant foundry are of similar nature to those of the manufacturer and even more complex. The parts built into steel mill machinery involve practically every field of ferrous and non-ferrous metals, and their service consists of being resistant to acid, abrasion, heat, friction, etc., also bearing properties for high speeds and high pressures, alloy metals that will prevent scratching of hot or cold strip steel in the manufacture of apron plates, guides, etc., material for resistance to shock loads and deformation. Heat treatment is necessary in practically all cases in developing the most desirable quality. The modern production foundry, in which schedules can be regulated for production of castings, can be ably equipped mechanically for greater production, more so than the so called jobbing or steel plant foundry which is constantly changing from one class of castings to another—from light weight one day to heavy weight the next day. It is, therefore, imperative that the entire organization be experienced in all classes of work encountered in steel plant maintenance. Such a foundry is called upon many times to produce castings on very short notice as unforeseen emergencies arise, necessitating changes in the schedule. These conditions have to be met, which in some cases increase the cost of castings in such emergencies. Generally speaking, however, the cost of manufacturing castings in a plant foundry is considerably less than purchasing on the market.

The foundry requirements for the average steel plant would consist of one acid open hearth furnace of 25 to 50 ton capacity, two cupolas for melting iron and iron alloys, 45 in. diameter, capable of melting 9 tons per hr., core ovens, mold drying ovens, and in some cases bins for drying molds, heat treating furnaces, all of which should be well insulated, these furnaces preferably to be gas fired and temperature controlled, mechanical facilities for the control of sand operation, and for large portion of the smaller castings, molding machines; correctly designed and constructed flasks play a most vital role in foundry production. Provisions must be made for the care and handling of flasks, otherwise the cost of this equipment will be excessive.

Air furnaces in iron foundries are constructed of brick sides, ends and roof with a sand bottom, fired from the ends with coal, using stack draft, the most modern type using pulverized coal. These furnaces are used to obtain large quantities of metal at one tapping, also the analysis can be changed after charging, whereas the desired analysis must be charged into a cupola and after charging cannot be changed except by ladle additions of various elements. This type of furnace is generally used in large manufacturing plants and is seldom found in the plant maintenance foundry.

Flasks are either constructed of wood or metal, according to the number of castings required or the type of mold (green or dry sand). The top half, or cope, which must be lifted off the lower part, or drag, must have bars that closely follow the contour of the pattern to help hold the sand in place.

In the manufacture of non-ferrous metals, brass, bronze and babbitt, precautions in every step must be exercised. In the melting, several types of equipment are available; all types have their merits and faults. The open flame furnace, constructed similar to a large barrel, fitted with worm gear drive for tilting, and refractory-lined, has a capacity for large quantities (approximately 2500 lb.) of metal from one furnace. The molten metal is separated from the flame by a layer of slag intentionally produced for this purpose.

The crucible (or pot), made from graphite, clay and other refractory materials, in capacities up to 1200 lb., is set into a brick-lined furnace which may be fired with coke, gas, or oil. After melting, alloying, etc., the crucible is used as a pouring ladle. Exponents of the crucible process believe that melting in smaller quantities gives better control, and separation of metal and flame produces a higher quality of metal.

The electric furnace has found many advocates and is desirable in many ways. Its chief fault is high cost of installation. Brass, which is commonly an alloy of copper and zinc; bronze which is composed of alloys of copper, tin, lead, nickel, aluminum, manganese, etc., require close control as to analysis. Melting not only means producing enough heat to put metal in the molten state, but control of the atmosphere in the furnace as well. A reducing atmosphere will cause the molten metal to absorb the reducing gases and cause pinholes throughout the casting. Oxides, or oxygen, are reduced by phosphorus. Correct pouring temperature must be observed to produce the highest quality. Babbitts, which have a base of tin, or lead, according to the uses they are made for, have other elements in their composition for hardening, friction resistance, resistance to distortion, etc., these being antimony, copper, nickel, etc. Mixing and melting are very important as a few degrees too much heat will seriously alter the structure of the finished metal.

Pneumatic tools, such as sand rammers, chipping hammers, hand grinders, vibrating machines for screening sand, etc., are standard equipment. Revolving barrel cleaners, stationary grinders, overhead cranes of not less than 25-ton capacity, monorail and jib cranes in the core room and brass floor, storage yard adjacent

to main building, are some of the items required for foundry production.

WELDING SHOP

As previously stated, this shop can best serve the average steel plant when used in conjunction with the boiler and structural shop, as modern methods in the fabrication of structural shapes, plate, and tank construction involve the science of welding to such a degree as to consider these shops as a single unit. However, not only structural fabrication, but practically all classes of maintenance welding will be found in a steel plant welding shop; also a large portion of welding performed and supervised by the personnel of this shop is done in every department of the plant, hence the necessity for highly trained welders, not only in structural fabrication but also welding of ferrous and nonferrous metals, supervised by a specialist in the several applications of welding. In order to protect the personnel of this department from the flash of the electric arc, special precautions must be taken. Partitioned booths, approximately 20 ft. square, should be erected on one side of the shop, of sufficient number to accommodate the number of electric welders employed, and portable screens with which to erect such a booth when welding large sections or when welding in other departments of the plant. A concrete pit, 10 ft. deep, 15 ft. square, will be found useful for work of excessive length or that must be placed on end. Three acetylene generators of 100 lb. carbide capacity, equipped with automatic control, should be provided, and for these special housing facilities are necessary. This building should be separate and apart from the main building and of fireproof construction, with ample capacity for the storage of one and a half carload of carbide, also either proper sewage connection or settling basin for the disposal of sludge from the generators. The acetylene gas generated by this station is piped to the several shops, and in some cases to other departments for use in cutting and welding where necessary, thereby eliminating the cost of cylinder handling. These generators should be serviced by a capable attendant.

Electric welding machines, both stationary and portable, of capacities ranging from 300 to 800 amperes, are considered standard for this shop. In the selection of these machines it will be found economical to use machines of the same manufacture. This will result in less maintenance cost in that spare part inventories can be kept to a minimum. This is also true of acetylene torch and regulator equipment.

A table of heavy cast iron construction, approximately 10 x 15 ft. square, for fitting together and holding securely parts to be welded, will save time, insure proper alignment, and accuracy of dimensions.

An annealing furnace, preferably gas fired, and automatically controlled, is indispensable for relieving stresses set up during the process of welding, approximate size 10 x 20 x 8 ft. Position finders of different sizes will promote ease of operation and reduce welding time as this equipment makes possible placing the parts to be welded in a horizontal position, thereby eliminating the slow process of vertical or overhead welding. In this shop, as well as the boiler and structrual shop, portable and stationary acetylene cutting machines are very necessary for the duplication and accuracy of dimensions in the fabrication of welded parts. These machines provide the minimum in gas consumption and maximum in production.

In regard to the oxygen supply, this would be furnished from the same source as mentioned in reference to the boiler and structural shop.

The welding shop tool room affords service not only to this particular shop, but the entire plant, in that here the maintenance and inspection of all acetylene torches, regulators, hose, etc., is done, and a complete record kept of such equipment.

Assuming that a weld is no better than the ability of the welder, a system of checking welds should be established. Test specimens of weld are made and sent to the plant laboratories for inspection.

Through close cooperation of this shop and the foundry, a method has been perfected whereby it is possible and practical to replace the necks of work rolls after same have been broken in service in strip mills. It is no longer necessary to scrap rolls due to broken necks as the neck can be economically renewed and full life of the roll assured.

PIPE SHOP

The building for this shop, while of the same design and accommodations for heating, light, service building, etc., does not require the floor space or personnel due to advanced methods of fabrication as was formerly necessary. Likewise, the machine tool equipment is considerably reduced. Modern methods of welding in the construction of manifolds, headers, and of pipe lines in general has eliminated old methods wherein all pipe was threaded. However, pipe fitting in the steel plant, especially in the smaller sizes, still requires threaded pipe and occasionally the larger size, necessitating threading and cutting off machines of a capacity of 12 in. and smaller. It has become standard practice in the fabrication and installation of pipe lines to eliminate as much as possible pipe fitting, *i.e.*, ells, tees, branch fitting, etc. For this reason, a bending table with heating furnace, dies of several sizes, bending machines for the smaller sizes, jib crane for handling larger size pipe must be provided. Hydraulic test pump, preferably of portable design, a drill press for drilling flanges, fittings, hangers, etc., sand blasting unit for cleaning interior of pipe, hand dies, work benches, stationary and portable, also portable threading machine for small pipe are some of the miscellaneous items of equipment necessary for the efficient performance of this department. A portion of this shop should be assigned to the salvaging of valves and fittings, with proper facilities for storing same; also ample storage space for pipe, commonly known as the pipe rack, should be provided.

The personnel of this shop should be thoroughly familiar with locations of the various main, and branch water, gas, air and steam lines, in order to be able to trace any trouble in these lines at any point from the source of supply to final point of consumption.

CARPENTER AND PATTERN SHOP

The nature of this class of steel plant maintenance, so far as materials are concerned, can be confined to a single building, however, the machinery for pattern making, *viz.*, planers, jointers, sanding machines, rip saws, lathes, etc., should not be used for the general run of carpenter work. Since practically all pattern lumber is white pine, the above machines must be kept in condition for machining this soft lumber, and other machines provided for hard wood, yellow pine, etc.

The portion of this shop provided for pattern making should be equipped with a work bench and layout table for each pattern maker, and the machinery conveniently located so as to be easily accessible to the benches. Space must be provided in this building for storing at least one carload of white pine of various sizes, as this material is expensive and must be kept dry.

Equipment for the disposal of dust and shavings, particularly at planers, jointers, sanders, etc., should be provided. In some states this equipment is mandatory. It is imperative that the machines in this shop be equipped with practical safety devices that will permit efficient operation and afford the maximum protection for the operator.

A pattern storage building of fire-proof design in which a sprinkler system is installed for protection against interior fires should be provided adjacent to the foundry. The transfer of patterns to and from this storage should be supervised by a competent attendant and a record of all patterns controlled by a card index system.

The duties of maintenance carpentry, more so than any other shop are performed in every department of the plant. In maintenance of buildings, form work for foundations, and brick work, trestle maintenance, etc., the personnel of this shop should be especially familiar with each department in order to avoid conflicting with operations in planning their work, and provide the necessary safeguards for their own protection as well as that of others.

A lumber yard must be provided adjacent to the shop, same to be partially covered for the storage of lumber and other building materials.

SHOP MANAGEMENT

Apprentice training is one of the oldest forms of education known to man. Today, with machinery so far advanced, workmanship requiring greater skill must be developed and this can only be done by a systematic educational apprentice training program. Individual opportunity for thoroughly trained craftsmen increases day by day. Young men who wish to become master craftsmen and proficient in their chosen life's work must be trained in the fundamentals of the mechanic's trade. No formula has ever been discovered that will replace practical experience. All progress in mechanical engineering depends upon the basic knowledge possessed by good craftsmen. During the past decade, due to uncertain economic conditions in industry, apprentice training has in many instances been neglected, particularly in steel plants where curtailed operations have necessitated reduction in personnel. Thus, today we find ourselves confronted with an insufficient supply of skilled craftsmen; however, it is gratifying to note that with the present trend of business moving in a positive direction toward stability, greater interest is being manifested in this all-important subject.

The methods of apprentice training, as the methods of industry in general, have progressed far beyond the stage of placing a young man in a shop to work with journeymen craftsmen, and after a period of four years considering him as having served his time, so to speak. The all-important factor of such present-day training must be the quality of craftsmen we are producing. Naturally, there are many systems of apprentice training—that of a steel mill will differ considerably from that of the automotive or machine tool industries, nevertheless, the fundamental principles are identical and should afford technical as well as practical training.

The training of personnel is not confined to the apprentices alone, rather a continual process of training the entire personnel, journeymen as well as apprentices, along the lines of better methods and creating interest in the individual to that end—that the work at hand is being done as a matter of accomplishment and not only for the compensation it represents. In the shops department the human element plays a prominent part, perhaps more so than in any other department of the plant, hence the necessity for the higher type personnel, of intelligence that will insure a rapid assimilation of maintenance problems.

Shop rates, like those of other departments, are a matter of company policy and vary to some extent in different localities. In addition to the established hourly base rate, many shops operate on the incentive or bonus system, however, this system is debatable inasmuch as it has proven successful in some shops and failed in others. There has been quite some controversy on the question of location of shop equipment resulting in difference of opinion; there are those who support the idea that a certain amount of shop equipment should be installed in each operating department, others that the centralized system is preferable. It would seem that this is a matter in which the geographical layout of the plant should be considered; in the larger plants where departments are separated from each other at considerable distance, the necessity for a limited amount of shop equipment in each department is justified, otherwise the centralized system would seem to be the most economical.

Considering again the matter of modernizing shop practice, we are greatly indebted to the machine tool builders for the excellent progress they have made in modernizing shop tools, and to the tool steel manufacturers for the improvements made in higher quality tungsten carbide tools, thereby making possible higher cutting speeds.

Practically all shop departments are operated on a budget system based either on total man hours worked in the entire plant, or on total tonnage produced. We prefer the former as this system provides a given rate per hour for each shop based on the total man hours worked in the entire plant which provides a given amount of shop budget regardless of tonnage.

A system of ordering material from the shops is usually provided, but whatever system is adopted, expediting is necessary. The shop expeditor is contacted daily by those ordering material. By this system, work

is scheduled through the shops and delivered to the several departments and is usually on hand when needed. The system of shop ordering that we find best adaptable to our particular set-up, after having tried several, is the one by which the department ordering the material issues the shop order in duplicate with all necessary information and drawings, both copies of the order being sent to the shop office where it is given a number; one copy is retained in the shop office and the other returned to the point of origin.

The shop copy is handled by the expeditor; additional copies of the order are made for as many shops as are involved. When the work has been completed, the original order is returned to the foreman who ordered the material, the order showing date of completion.

A hauling order is issued to the transportation department for delivery of the material. Each department in the plant has its specific charge account, as well as each unit in the department, making it comparatively easy to check the cost of any job at will.

In addition to regular running repairs, there is always more or less construction work going through the shops. This work usually originates in the engineering department and is handled by shop orders in exactly the same manner as the regular repair work. We find, that owing to the simplicity of this system, office personnel and routine are reduced to a minimum.

DISCUSSION

PRESENTED BY

RICHARD D. WEARNE, *Superintendent of Shops*, Carnegie-Illinois Steel Corporation, Gary, Indiana.

RICHARD D. WEARNE: One of the subjects of interest to me in Mr. Moxley's paper was his reference to apprentices. I don't suppose we are all agreed on how these should be handled, but it seems to me there are two factors which should be considered before we decide to sign up a man for four years.

First, are we entitled to take four years of a man's time without compensating him properly for the time spent, or should we prepare him for a special occupation since the modern trend seems to be in specializing? I know that a difference of opinion exists on these points and the value of mechanics developed by the latter method, but if we take 100 boys and start them through the "school of experience," the first four years are spent in acquiring fundamental knowledge. It will then take another four to eight years to develop their skill and broaden their knowledge to that of a recognized good, all around mechanic, while the latter system gives to the shop in two years a man capable of producing on one of the various machines work comparable to that produced by the more versatile apprentice with four to six years of training.

This modern trend is something that has come from mass production and the increasing demand for larger shops in centralized maintenance, where a journeyman machinist is not essential for every machine, and about 75 per cent of the boys who finish their apprenticeship will, at the end of two to three years, be found working on one of several groups of machines, either on cylindrical or plane surface work, with a small percentage possibly working on gear cutters. This means that we could possibly have taken the same boys and, in two years, trained them to operate the same machines, giving them two to three productive years that under the apprentice system would have been used in training them to handle machines which we will not later ask them to operate.

At the end of ten years, probably 90 per cent of the boys have become specialists in one line or the other, and from the remaining 10 per cent we probably will develop our supervisors, and it is my opinion that these are the boys we should choose earlier in their training period and to whom special effort should be applied in their training.

As to the cost of maintaining a large machine shop, if you have a modern shop of your own you can probably answer the question best yourself, because a number of the larger machine shops in the industry at this time are more or less obsolete, making costs appear to be out of line. Most of you appreciate the fact that you need better machines, but unless you can show an appreciable saving over a short period of time the appropriation for new machines is not readily forthcoming. An approach to this perplexing problem for shop supervisors is to develop the unit costs on modern machines as against obsolete units now used and to present to management a statement of savings possible with modern machines and modern cutting tools.

This is the line we are pursuing at the present time to convince management that investment in modern tools is the road to lower costs and better shops.

An important item in every maintenance shop is the system by which work is scheduled to the machines. In a large shop it is important to schedule all work so that the job units reach the assembly floor in time to meet a predetermined schedule. Large numbers of orders released without careful consideration as to availability of machine time in the several groups will develop overloading, which, in turn, causes delays to schedules and a surplus of partly finished orders awaiting assembly.

In the smaller shops the foreman will probably do his own scheduling, but this in the large shops would occupy too much of the foreman's time and should be the function of a scheduling department, whose duties are to properly route and schedule the work in relation to availability of machine groups.

A. I. S. E. Philadelphia Section Celebrates Twenty-fifth Anniversary

On Saturday, January 4, the Philadelphia District Section celebrated its twenty-fifth anniversary. Founded in 1916, this Section has flourished and to-day is one of the Association's most active branches. As a token of appreciation for his twenty-five years of sincere and successful work as District Secretary, several gifts were presented to Linn O. Morrow, who is shown *(upper left)* with Chairman A. J. Fisher and National President W. A. Perry. During the celebration, D. M. Petty *(upper right)*, a Past President of the Association, reminisced on the early history of the Section and of the Association.

Shown below are some of the men who have served as Chairman of the Philadelphia Section: *(front row, left to right)* H. S. Boone, W. H. Burr, F. H. Woodhull, D. M. Petty, R. F. Gale, L. F. Coffin, N. C. Bye; *(back row)* A. J. Fisher, G. O. Van Artsdalen, H. H. Angel, L. V. Black, G. O. Pfeffer, H. D. Esterly, F. O. Schnure, and G. J. Walz.

William A. Perry

PRESIDENT, ASSOCIATION OF IRON AND STEEL ENGINEERS

The President's Message

Historians will have many pages well filled when the pertinent events of the year 1940 are recorded. World wide unrest, international, national and local happenings, in general, did not live up to that common saying, "Coming events cast their shadows before them." We live in a changing world.

We, the members of the Association of Iron and Steel Engineers, are able to look back over our record of the last year with extreme pride and satisfaction, for the unusual happenings of the year did not materially disturb our Association's purpose or program for making worth-while contributions of material benefit to the iron, steel and allied industries.

Our annual Iron and Steel Exposition and Convention was one of the best, not only in attendance and general interest in the exhibits but also from the excellence of exhibits and the abundance of fine engineering papers.

The recently elected national officers realize only too well the past achievements, the position attained and the necessity of this Association in the eyes of the iron and steel industry. Under the leadership of the very able officers who have preceded us the work has been carried on most efficiently. Collectively or singly, our publication, the *Iron and Steel Engineer*, is ample evidence of our efforts and essential service to this industry. The Association has done much to unify the ideas and efforts of the engineering, operating and maintenance divisions of the industry, to the mutual benefit of all concerned. Maintaining this enviable position and prestige in the industry entails much work and responsibility, which we gladly assume because we know of the unselfish enthusiasm of the members for the advancement of this Association and their desire to participate in the sharing of this work and responsibility.

At the threshold of a new year that promises to be one of the most uncertain in the history of our Association, it is heartening, indeed encouraging, to know that we are identified with and give our all to that very essential unit of our nation, either in time of peace or war, the iron, steel and allied industries. During this year the national preparedness program will take precedent over all other programs. This will be nothing unusual for you because as engineers you are continually developing, building and preparing the iron and steel industry for national defense. This happens in your regular, every day attention to your normal duties. Your initiative and resourcefulness, supplemented by personal contacts in meetings as well as written records of our Association in the *Iron and Steel Engineer*, will surely be of immeasurable value to you during this peak period of operations.

In order to carry on our work successfully during this year we need the continued enthusiasm of our members. They should be more generous in the presentation of engineering papers and discussions. This same enthusiasm which was behind the founding of our Association will be required to keep it in the high position it is now enjoying. The industry in which you work, the organization of which you are a member, and the nation in which you live need this service on your part and your president sincerely requests that there be no let up in your efforts in your chosen field.

T. E. HUGHES
FIRST VICE-PRESIDENT

NEWLY ELECTED OFFICERS *and* DIRECTORS

A. I. S. E.

1941

F. E. FLYNN
SECOND VICE-PRESIDENT

C. L. McG
TREAS

THOMAS E. HUGHES, superintendent of maintenance department, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania, has spent his entire business background in the steel industry. Mr. Hughes started to work with the Union Railroad in 1902, and successively worked at the Clairton Plant of the Carnegie-Illinois Steel Corporation, McKeesport Plant of the National Tube Company, Youngstown Plant of the Youngstown Sheet and Tube Company, and for the past twenty-eight years has been at the Duquesne Plant of the Carnegie-Illinois Steel Corporation. Mr. Hughes attended the public schools of Duquesne, and the night classes of the Carnegie Institute of Technology.

C. L. McGRANAHAN'S first work in the steel industry was in 1916 with the American Sheet and Tin Plate Company. He worked in various positions with that company's different plants until 1931, allowing for one year World War service. In 1931 he joined the Inland Steel Company as superintendent of the company's Indiana Harbor hot strip mill, resigning in February 1936, to take his present position as assistant general superintendent with the Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania. Mr. McGranahan was graduated from Pennsylvania State College in 1916 with a bachelor of science degree in civil engineering.

FRANK EDWARD FLYNN started in the steel business with the Superior Steel Company at Carnegie, progressing from the position of water boy to that of boss roller. In 1916, he started in charge of rolling at the Phillips Sheet and Tin Plate Company, which later became the Weirton Steel Company, and during his 11 years service there he became assistant manager and then manager. He went to the Trumbull Steel Company in 1928, as assistant vice president in charge of operations. This company later became a unit of Republic Steel Corporation, and he became district manager, with headquarters at Warren, Ohio.

J. LEDLIE MILLER has been employed in the steel industry since 1909, serving as messenger, draftsman, and in the experimental engineering department of Carnegie Steel until he joined the army, where he served overseas as a lieutenant in the heavy field artillery. Serving as fuel engineer at the Bellaire works of Carnegie from March 1919 until that fall, he returned to the Carnegie Institute of Technology where he received his degree in mechanical engineering the following year.

Mr. Miller returned to Bellaire as fuel engineer and when this plant was closed, went to the Follansbee Brothers plant in Toronto, where he was annealing department foreman and assistant metallurgist until January 1, 1925. He served as fuel engineer of the Wheeling Steel Corporation in the Wheeling district from 1925 until he went to Youngstown for Carnegie in 1928. He acted as assistant chief engineer of Carnegie-Illinois Steel Corporation in the Youngstown district from 1928 to 1936. In 1937 he was appointed assistant chief combustion engineer of Republic Steel Corporation with headquarters in Cleveland.

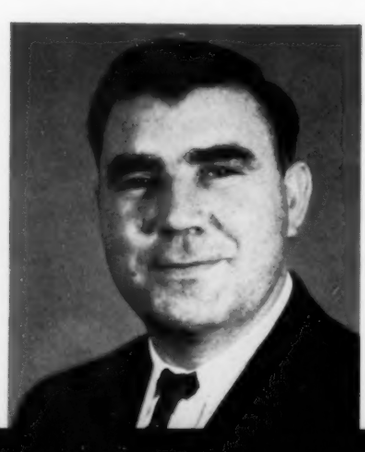
W. J. WILSON attended Birmingham, Alabama, public and private schools, business college, completed a correspondence course, and special vocational studies at the University of Alabama. Mr. Wilson began his electrical career in 1904 with the Schuler Brothers wire mill. In the same year he went with the mining division of the Tennessee Coal, Iron and Railroad Company, where he remained for about a year, returning to the Schuler Brothers wire mill. From there he went to Dimick Pipe Works. His next position was with the Southern Iron and Steel Company in Gadsden for a period of two and one-half years. In 1911 he left Gadsden to go with the American Cast Iron Pipe Company as chief electrician, from which he advanced to electrical superintendent, the position he holds at the present time.

ARTHUR R. DIBBEN began his electrical career as an electrical apprentice at Illinois Steel Company's South Works, Chicago, Illinois, in 1904. From 1909 until 1920 Mr. Dibben was employed by various steel plants and plants allied with the steel industry in and around the Chicago district. In 1920, he entered the employ of the Mark Manufacturing Company at Indiana Harbor, Indiana. This plant was later taken over by the Steel and Tube Company of America, and in turn was later absorbed by the Youngstown Sheet and Tube Company, where Mr. Dibben has continued in his work as assistant electrical superintendent. He studied electricity in the Chicago public evening schools.

I. N. TULL was born in Anniston, Alabama, raised in North Carolina attending public schools in Kinston, and State College at Raleigh, graduating with a B.E. degree in electrical engineering in 1910. For two years, between public school and college, he was employed by Carolina Tele-

I. N. TULL
DIRECTOR

L. J. GOULD
DIRECTOR



C. H. WILLIAMS
DIRECTOR

W. J. WILSON
DIRECTOR

GEORGE
DIRE

C. L. McGRANAHAN
TREASURER

J. L. MILLER
SECRETARY

S. M. JENKS
DIRECTOR

R. S. SHOEMAKER
DIRECTOR

phone and Telegraph Company as installer, lineman and general troubleman. For a short time after leaving college, he was employed by Southern Bell Telephone Company as a central office man at Columbia, South Carolina, leaving there to enter General Electric Company's test course at Schenectady. He was transferred to their Cleveland office's engineering department in 1912, remaining there until 1915, when he was employed by Corrigan, McKinney and Company as electrical engineer.

At that time, Corrigan, McKinney and Company operated through various operating companies only blast furnaces and metal mines, but had started to build additional blast furnaces and a steel plant at Cleveland, to be followed by extensive electrification of the iron mines, and the opening of coal mines. The ensuing twelve years were spent in engineering and construction work, and in 1927, general supervision of electrical maintenance and operations was added to those duties. After the merger with Republic Steel Corporation in 1935, Mr. Tull became electrical superintendent of the Cleveland District for Republic.

R. S. SHOEMAKER started his steel career at the Lorain plant of the National Tube Company about 1903 as electrical construction foreman. In 1905 he was appointed electrical superintendent for the Milliken Brothers, Inc., of New York. He became electrical superintendent at the Monessen plant of the Pittsburgh Steel Company in 1907, and in 1909 was appointed assistant consulting engineer in charge of electric construction at the Algoma Steel Corporation, Ltd., Sault Ste. Marie, Ontario, Canada. During the year 1912 he was employed by the St. Lawrence Bridge Company and the Dominion Bridge Company as electrical superintendent of their plants and in charge of electrical and mechanical maintenance during the erection of the Quebec Bridge at Quebec.

Mr. Shoemaker joined the American Rolling Mill Company, Middletown, Ohio, in 1916 as superintendent of maintenance, in 1928 became superintendent of blooming, bar and strip mills, and in 1938 was appointed lubrication engineer.

GEORGE C. PFEFFER entered the employ of R. D. Wood Company at the Camden Iron Works in 1907 as electrician. Mr. Pfeffer transferred to the Florence Pipe Foundry and Machine Company, Florence, New Jersey, in 1911 as assistant to the chief electrician. In 1914 he was advanced to the position of chief electrician, and in 1936 was placed in charge of all power in addition to electric power.

FREEMAN H. DYKE graduated from Phillip Andover Academy and from the Massachusetts Institute of Technology. Mr. Dyke started in the steel business with the Wheeling Steel Corporation at their Portsmouth plant in 1920, and with the exception of three years with the Jones and Laughlin Steel Corporation he has been with Wheeling Steel Corporation continuously. After serving in several capacities in various departments, Mr. Dyke became superintendent of the blooming, bar and hot strip mills at the Steubenville plant.

C. H. WILLIAMS was graduated from the University of Colorado, College of Engineering, in 1926, and was employed by the Jones and Laughlin Steel Corporation, South Side Works, Pittsburgh, as shear foreman in September of that year. In June, 1927, he was junior engineer in the power engineering department of the National Tube Company, in the Pittsburgh plant. In April, 1930, Mr. Williams joined the Carnegie Steel Company, Youngstown district, as junior engineer in the steam engineering department. He successively served as power and fuel engineer and assistant chief engineer of the Youngstown district. In August, 1940, he was transferred to the Pittsburgh office of the Carnegie-Illinois Steel Corporation as power and fuel engineer on the staff of the chief engineer. In December, 1940, he was appointed assistant chief engineer, Carnegie-Illinois Steel Corporation, Pittsburgh district.

STEPHEN M. JENKS, a graduate of Cornell University with a degree of mechanical engineer, has been connected with the United States Steel Corporation subsidiaries since 1925. Mr. Jenks began in the engineering department of the American Sheet and Tin Plate Company, after two years' previous experience as a blast furnace blower with the Jones and Laughlin Steel Corporation. He went to the Gary sheet and tin mills in 1929 as a fuel engineer. In 1933 he was transferred to Pittsburgh as power engineer of the company. From 1935 to 1936, he was made assistant chief engineer of the company, and when the American Sheet and Tin Plate Company became part of the Carnegie-Illinois Steel Corporation, he was made chief engineer of the construction division. Mr. Jenks returned to Gary, February, 1937, as chief engineer of the Gary Works, and remained in this capacity until October of the same year, when he was appointed assistant general superintendent. In December, 1940, Mr. Jenks was appointed to the position of general superintendent of the Gary Works.

GEORGE C. PFEFFER
DIRECTOR

ARTHUR R. DIBBEN
DIRECTOR

FREEMAN H. DYKE
DIRECTOR

P. F. KINYOUN
DIRECTOR-AT-LARGE

National Committees for 1941

ASSOCIATION OF IRON AND STEEL ENGINEERS

General Chairman—WILLIAM A. PERRY, *President*

ADVISORY COMMITTEE
Past Presidents, A. I. S. E.

1907–1908 JAMES FARRINGTON, *Electrical Superintendent*, Wheeling Steel Corporation, Steubenville, Ohio.

1909 JOHN C. REED, *Electrical Superintendent*, Bethlehem Steel Company, Steelton, Pennsylvania.

1910 F. P. TOWNSEND, *Engineer*, Copperweld Steel Company, Glassport, Pennsylvania.

1911 L. R. PALMER, *Conservation Engineer*, Safety Department, Equitable Life Assurance Society of U. S., New York, New York.

1914 E. FRIEDLANDER, Pittsburgh, Pennsylvania.

1917 F. D. EGAN, *Electrical Superintendent*, Bethlehem Steel Company, Lackawanna, New York.

1919 D. M. PETTY, *Superintendent Service Division*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

1921 E. S. JEFFERIES, *General Manager*, Universal Boring Machine Company, Hudson, Massachusetts.

1922 W. S. HALL, *Chief Engineer*, Chicago District, Carnegie-Illinois Steel Corporation, Chicago, Illinois.

1923 R. B. GERHARDT, *Chief Engineer of Construction*, Bethlehem Steel Company, Bethlehem, Pennsylvania.

1924 R. S. SHOEMAKER, *Lubrication Engineer*, American Rolling Mill Company, Middletown, Ohio.

1925 *Chairman:* A. C. CUMMINS, *General Superintendent*, Youngstown District, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

1926 G. H. SCHAEFFER, *Electrical Engineer*, Carpenter Steel Company, Reading, Pennsylvania.

1927 S. S. WALES (Retired), Box B, Westside Station, Youngstown, Ohio.

1930 F. W. CRAMER, *Electrical Engineer*, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

1931 F. O. SCHNURE, *Electrical Superintendent*, Bethlehem Steel Company, Sparrows Point, Maryland.

1932 J. J. BOOTH, *Assistant Superintendent of Maintenance*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

1933 J. D. DONOVAN, *Electrical and Mechanical Superintendent*, Republic Steel Corporation, Massillon, Ohio.

1935 W. H. BURR, *Electrical Superintendent*, Lukens Steel Company, Coatesville, Pennsylvania.

1936 G. R. CARROLL, *Assistant Superintendent of Maintenance*, Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania.

1937 H. G. R. BENNETT, *Engineer*, Hot Rolling Mills, Carnegie-Illinois Steel Corporation, Pittsburgh, Pensnylvania.

1938 L. F. COFFIN, *Superintendent*, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland.

1939 C. CLARKE WALES, *Vice-President*, Hamilton Bridge Company, Hamilton, Ontario, Canada.

1940 J. A. CLAUSS, *Chief Engineer*, Great Lakes Steel Corporation, Ecorse, Michigan.

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Chairman: THOMAS E. HUGHES, *Superintendent of Maintenance*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

G. R. CARROLL, *Assistant Superintendent of Maintenance*, Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania.

F. H. DYKE, *Superintendent*, Blooming, Bar and Hot Strip Mills, Wheeling Steel Corporation, Steubenville, Ohio.

H. T. WATTS, *Combustion Engineer*, Republic Steel Corporation, Gadsden, Alabama.

A. L. LEMON, *District Manager*, Reliance Electric and Manufacturing Company, Birmingham, Alabama.

H. R. MIDDLEBROOK, *Assistant Division Superintendent of Maintenance*, Carnegie-Illinois Steel Corporation, Gary, Indiana.

A. J. WHITCOMB, *Electrical Engineer*, Freyn Engineering Company, Chicago, Illinois.

T. B. McELRAY, *Superintendent of Electric Light and Power*, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

W. W. SPANAGEL, *District Manager*, Reliance Electric and Manufacturing Company, Cleveland, Ohio.

A. J. F. MacQUEEN, *Superintendent of Maintenance*, Rotary Electric Steel Company, Detroit, Michigan.

E. F. WEISS, *District Manager*, Cutler-Hammer, Inc., Milwaukee, Wisconsin.

A. J. FISHER, *Fuel Engineer*, Bethlehem Steel Company, Sparrows Point, Maryland.

L. O. MORROW, Schaff Building, Philadelphia, Pennsylvania.

C. L. McGRANAHAN, *Assistant General Superintendent*, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

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JAMES FARRINGTON, *Electrical Superintendent*, Wheeling Steel Corporation, Steubenville, Ohio.

W. A. PERRY, *Superintendent*, Electrical and Power Departments, Inland Steel Company, East Chicago, Indiana.

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Following committees to be appointed when and as required:

Mechanical Division
Electrical Division
Combustion Division
Lubrication Division
Welding Division
Operating Practice Division
General Division

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J. D. JONES, *Chairman,* Mechanical Engineering Division

A. J. FISHER, *Chairman,* Combustion Engineering Division

T. R. MOXLEY, *Chairman,* Lubrication Engineering Division

A. W. STEED, *Chairman,* Welding Engineering Division

F. E. FLYNN, *Chairman,* Operating Practice Division

W. H. BURR, *Chairman,* Development Report Committee

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L. A. WYND, *Electrical Superintendent,* Republic Steel Corporation, East Chicago, Indiana.

A. W. DUNCAN, *Electrical Superintendent,* Weirton Steel Company, Weirton, West Virginia.

F. W. CRAMER, *Electrical Engineer,* Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

ERNEST L. HUFF, *Electrical Engineer,* Allegheny-Ludlum Steel Corporation, Brackenridge, Pennsylvania.

GEORGE A. KAUFMAN, *Electrical Engineer,* Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

E. G. SCHLUP, *Electrical Engineer,* American Rolling Mill Company, Middletown, Ohio.

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LEONARD LARSON, *Chief Engineer,* Republic Steel Corporation, Cleveland, Ohio.

JULIUS GRAF, *Assistant Chief Engineer,* Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

W. T. RYAN, *Chief Engineer,* Wheeling Steel Corporation, Steubenville, Ohio.

ROBERT BACKUS, *Superintendent,* Mechanical Department, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

LUBRICATION ENGINEERING DIVISION

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C. R. HAND, *Lubrication Engineer,* Bethlehem Steel Company, Sparrows Point, Maryland.

H. R. GILCHRIST, *Lubrication Engineer,* Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

F. L. GRAY, *Lubrication Engineer,* Carnegie-Illinois Steel Corporation, Gary, Indiana.

F. J. THOMAS, *Lubrication Engineer,* Republic Steel Corporation, Cleveland, Ohio.

H. H. SHAKELY, *Master Mechanic,* Strip Mills, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

WELDING ENGINEERING DIVISION

Chairman: A. W. STEED, *Maintenance Superintendent,* American Rolling Mill Company, Middletown, Ohio.

L. J. GOULD, *Assistant Chief Engineer of Construction,* Bethlehem Steel Company, Bethlehem, Pennsylvania.

H. F. RAAB, *Assistant Maintenance Superintendent,* Bethlehem Steel Company, Johnstown, Pennsylvania.

J. J. BOOTH, *Assistant Superintendent of Maintenance,* Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

H. E. MEYER, *General Master Mechanic,* Great Lakes Steel Corporation, Ecorse, Michigan.

H. E. DAVIS, *Superintendent of Maintenance,* Republic Steel Corporation, Buffalo, New York.

M. M. MacDONALD, *Electrical Superintendent,* Andrews Steel Company, Newport, Kentucky.

W. D. CLEAVINGER, *Mechanical Superintendent,* Youngstown Sheet and Tube Company, East Chicago, Indiana.

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FRANKLIN C. FRYE, *Steam and Fuel Engineer,* Great Lakes Steel Corporation, Ecorse, Michigan.

F. E. LEAHY, *Superintendent,* Fuel Department, Youngstown Sheet and Tube Company, Youngstown, Ohio.

J. L. MILLER, *Assistant Chief Combustion Engineer,* Republic Steel Corporation, Cleveland, Ohio.

LEE A. KLINE, *Assistant Chief Power and Fuel Engineer,* Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

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C. P. BETZ, *Assistant Manager,* Hanna Furnace Division, Great Lakes Steel Corporation, Ecorse, Michigan.

E. W. STEINWEG, *Superintendent,* Coke Plant, Youngstown Sheet and Tube Company, East Chicago, Indiana.

J. H. VOHR, *General Superintendent,* Granite City Steel Company, Granite City, Illinois.

W. C. McCONNELL, *Plant Superintendent,* Republic Steel Corporation, Massillon, Ohio.

LOUIS MOSES, *Superintendent,* Rail Mill and Roll Department, Bethlehem Steel Company, Sparrows Point, Maryland.

CONSULTANTS • DESIGNERS AND BUILDERS TO THE

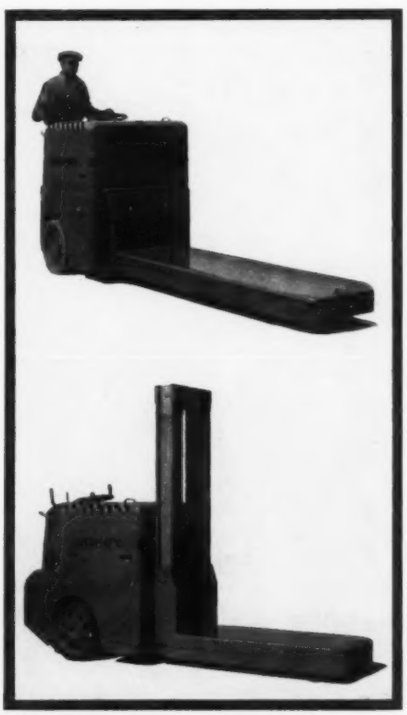
MATERIAL HANDLING SPEEDED BY VARIOUS NEW TRUCK DEVELOPMENTS

▲ Among the many important developments in the truck industry during the year 1940 were two trucks brought out late in the year by the Automatic Transportation Company, a division of the Yale and Towne Manufacturing Company. These new five ton capacity low and high lift platform trucks have been designed so that utmost maneuverability is obtained. Completely new in every detail of engineering, control, construction, and performance, the two models have the following sizes: Model TLO-5 high-lift standard platform—60 in. long, 26¼ in. wide, 11 in. high, and 60 in. lift. Model LO-5 low-lift standard platform—60 in. long, 26 in. wide, 11 in. high.

These trucks have smooth, safe, top speed acceleration and deceleration with positive no-plug forward and reverse travel action with full magnetic drive and lift control. Utilized is a high efficiency standardized spiral bevel and spur gear drive. The hoist is driven by a roller chain with triple-spur gear transmission precision mounted in horizontal split housing. Low maintenance costs are obtained by the use of over 50 anti-friction bearings.

Other developments during the year 1940 include the Automatic power steer which has follow-through indicator type handle. This feature automatically indicates to the operator the exact positions of the wheels when the truck is turning with relation to the truck or tractor. This improvement offers the operator speedier steering control than heretofore. Among the mechanical designs for the past year was a new heavy duty motor which incorporates simplified commutator head, which affords complete access to commutator and brushes.

Designed to eliminate bottlenecks in the flow of industrial materials, both of the trucks shown below are of five ton capacity and are capable of high speed transportation with utmost safety.



CRUCIBLE WILL EXPAND MIDLAND STEEL PLANT

▲ Crucible Steel Company of America will spend about $10,000,000 in plant expansion in the next two years. Most of the expenditures will be made for improvements at the works of the Pittsburgh Crucible Steel Company, its subsidiary, at Midland, Pennsylvania. Installation of a new strip mill, electric furnaces and auxiliary equipment will take place at Midland.

Consolidation of the operations of the Anderson du Puy spring works at McKees Rocks, Pennsylvania, with those of the Park works in Pittsburgh or the Midland works is being considered and certain operations heretofore carried on at its Spaulding and Jennings works in Jersey City, New Jersey, will soon be completely consolidated in its Halcomb works at Syracuse, New York.

OTIS STEEL TO IMPROVE RIVERSIDE STRIP MILLS

▲ Otis Steel Company has announced a $750,000 program of improvements at its Riverside plant in Cleveland, Ohio.

Part of this program is already under way and the balance will go forward as promptly as materials can be brought in. The program, in part, provides for increased annealing facilities for sheet and cold rolled strip mills and additional soaking pit capacity at the blooming mill. The program also contemplates improvements in the company's coke works and the installation of new turbo blowers and high-pressure boilers at the blast furnaces.

WISCONSIN STEEL WORKS EXPANDS INGOT CAPACITY

▲ International Harvester Company will expand the ingot capacity of its Wisconsin Steel Works at South Chicago, Illinois, by the addition of two open-hearth furnaces in order to even up production between its originating and finishing mill operations. Con-

struction is to begin at once with the hope that the two new furnaces will be ready by the end of 1941.

The two furnaces will bring to 11 the number of open hearths at the Wisconsin Steel works. Present annual capacity is 480,000 gross tons of finished steel. Capacity on completion of the new furnaces will be approximately 580,000 gross tons, an increase of about 20 per cent.

In addition to the furnaces the company will install auxiliary equipment consisting of ladle cranes, a charging machine and a new soaking pit. Total cost of the improvements and additions will approximate $1,500,000.

BEARING FIRM ADDS TO MANUFACTURING SPACE

▲ SKF Industries, Inc., manufacturers of ball and roller bearings, is erecting an addition of 56,200 sq. ft. of manufacturing floor space to plant No. 2, in Philadelphia. This building is fire proof, saw-tooth construction, conforming to the design of the main building.

In addition, a two-story brick wing enclosing 12,000 sq. ft. is extending office facilities at plant No. 1, bringing the total enclosed area of both plants to 666,600 sq. ft.

U. S. STEEL AWARDS COKE OVEN CONTRACT

▲ Tennessee Coal, Iron and Railroad Company has awarded a contract for erection of a battery of 73 coke ovens at the Fairfield Works, Fairfield, Alabama. The contract, it was learned, was awarded to the Koppers Company.

These ovens are a part of the general expansion program of the Tennessee company announced on Nov. 13. They will be erected adjacent to the existing coke oven batteries and will be known as battery No. 4. Work is expected to be completed by early fall of 1941. When these ovens have been completed there will be a total of 436 ovens at the Fairfield plant, having capacity for the production of 2,330,000 net tons of coke annually. In addition to the coke ovens, certain equipment will be added to the present by-product plant.

INSULATING FIRE BRICK CHANGES BRAND NAMES

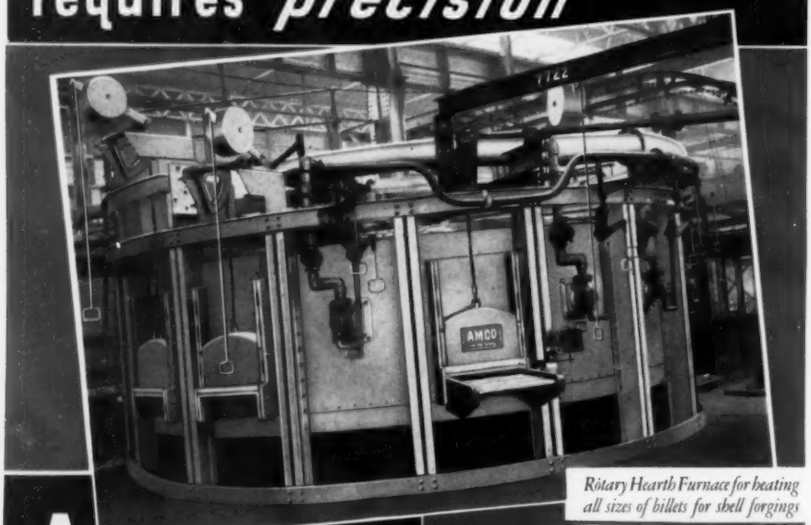
▲ The building materials division of the Armstrong Cork Company has announced a change in brand names of Armstrong's insulating fire brick, and the use of different color spots at the end of each brick for easy identification of the various types. The following changes in names and identification will be made:

N-16, light-duty brick for use with temperatures up to 1600 degrees F., becomes A-16, and is identified by its distinctive red-brown color.

N-20, the light-duty brick for use with temperatures up to 2000 degrees F., will be known as A-20. Identification is simplified by a blue color spot stamped on the end.

A-25, for light-duty use with temperatures up to 2500 degrees F., remains unchanged, but an orange color spot at the end of the brick helps identification.

Heating ordnance materials requires *precision*

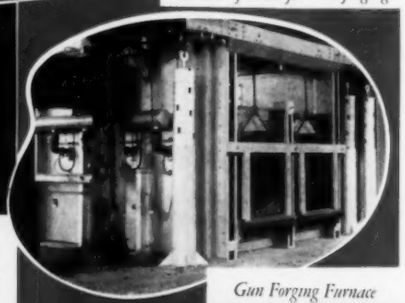


Rotary Hearth Furnace for heating all sizes of billets for shell forgings

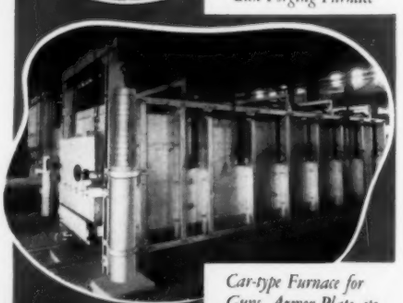
AMCO FURNACES

..have successfully met this vital need

The heating of shell and gun forgings calls for *uniform temperatures!* AMCO FURNACES are modern versions of *designs proved in actual service*...the acid test for such important operations. Write for details on the complete line of AMCO Furnaces, one of which will no doubt serve your particular purpose!



Gun Forging Furnace



Car-type Furnace for Guns, Armor Plate, etc.

The Amsler-Morton Company

FULTON BUILDING • PITTSBURGH, PA.

For heavy-duty use with temperatures up to 2300 degrees F., EF-23 becomes A-23, and is identified by a green color spot on the end of the brick.

EF-26, for use with temperatures up to 2600 degrees F., on the hot face, is changed to A-26 and is identified by a red color spot placed on the end of the brick.

The change has been made solely for simplification purposes, with no change in the formulation or method of manufacture of any of the five brands.

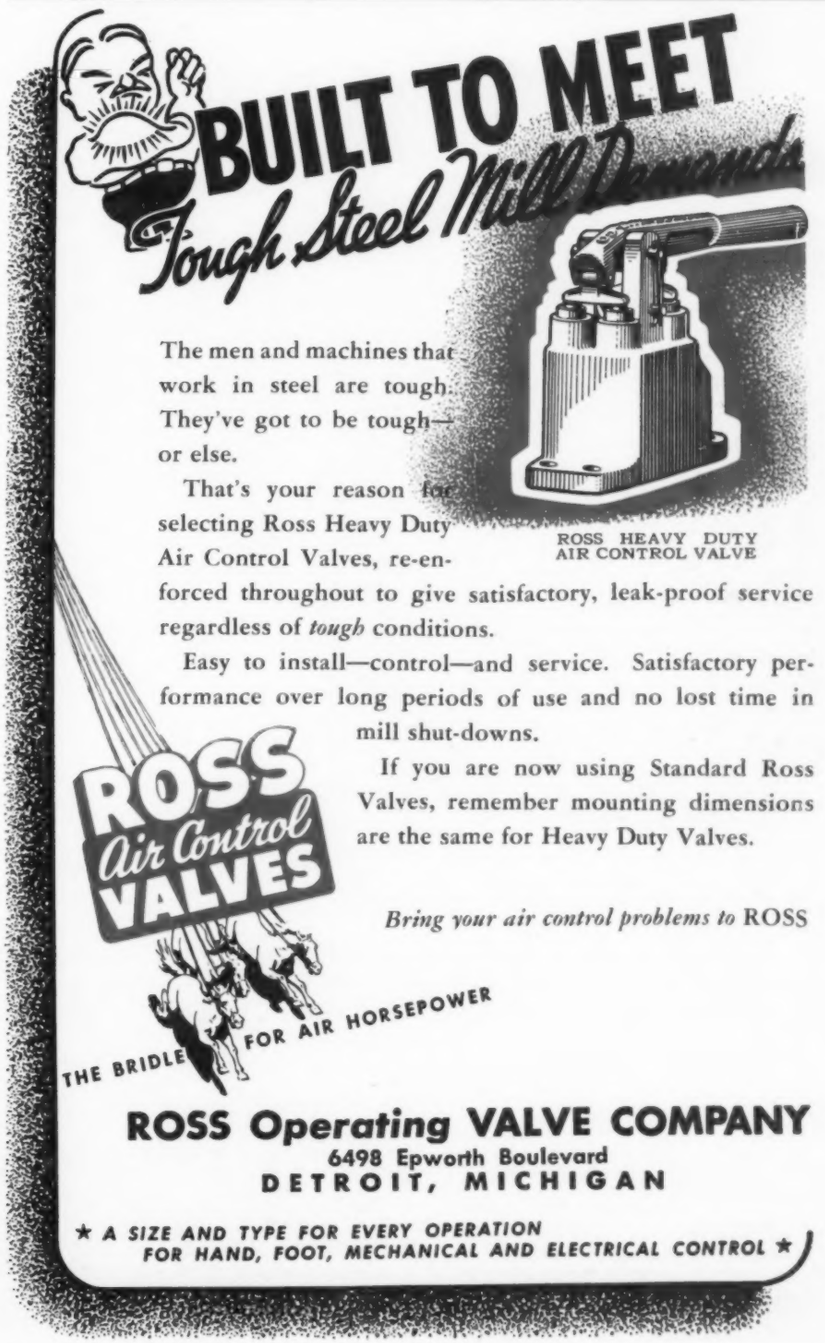
EXTENSIVE CHANGES IN NEW INDUCTION MOTORS

▲ As a result of a broad survey of the changing requirements of its industrial customers, the General Electric Company has announced an entire line of completely new polyphase induction motors, in integral horsepower sizes, to conform with new industrial trends, processes, and practices. Known as the "Tri-Clad" motor and representing one of the most extensive product changes in the history of the company, it has called for many new methods in General Electric motor manufacturing.

In all its ratings it features modern streamlined appearance; more complete protection, through the use of a cast-iron frame, than heretofore available except in especially enclosed machines; major advances in the insulation of current-carrying parts; and improved bearing design and lubricating arrangements. At the same time, it incorporates the cast-aluminum rotor, pressure-relief system of greasing for ball-bearing motors, and other proven features. In addition, however, it offers many new convenience features.

In recent years there has been an increasing and widespread demand for more protective features in open, general-purpose motors. Thus, despite its striking modern appearance, major industrial interest in the new motor will undoubtedly center around its outstanding mechanical and electrical protective features. In place of the conventional open frame, it makes use of a cast-iron frame of the box type. The end shields are designed to match the frame and are enclosed above the centerline. This combination of frame and end shields minimizes contact of vital motor parts with foreign material such as lubricants, coolants, and other liquids, as well as chips, tacks, etc., while also protecting it against accidental blows in handling or similar rough usage. The new-type insulation, dust-tight bearings, and the use of "Glyptal" in the priming and finishing paints

After extensively surveying the changing requirements of industrial users, a completely new line of polyphase induction motors has been brought out to conform with the new industrial trends. The introduction of these motors necessitated broad changes in the methods of manufacture.


BUILT TO MEET
Tough Steel Mill Demands
The men and machines that work in steel are tough. They've got to be tough—or else.
That's your reason for selecting Ross Heavy Duty Air Control Valves, re-enforced throughout to give satisfactory, leak-proof service regardless of *tough* conditions.
ROSS HEAVY DUTY AIR CONTROL VALVE
Easy to install—control—and service. Satisfactory performance over long periods of use and no lost time in mill shut-downs.
If you are now using Standard Ross Valves, remember mounting dimensions are the same for Heavy Duty Valves.
Bring your air control problems to ROSS
ROSS Air Control VALVES
THE BRIDLE FOR AIR HORSEPOWER
ROSS Operating VALVE COMPANY
6498 Epworth Boulevard
DETROIT, MICHIGAN
★ A SIZE AND TYPE FOR EVERY OPERATION FOR HAND, FOOT, MECHANICAL AND ELECTRICAL CONTROL ★

armor it against the attack of harmful agents.

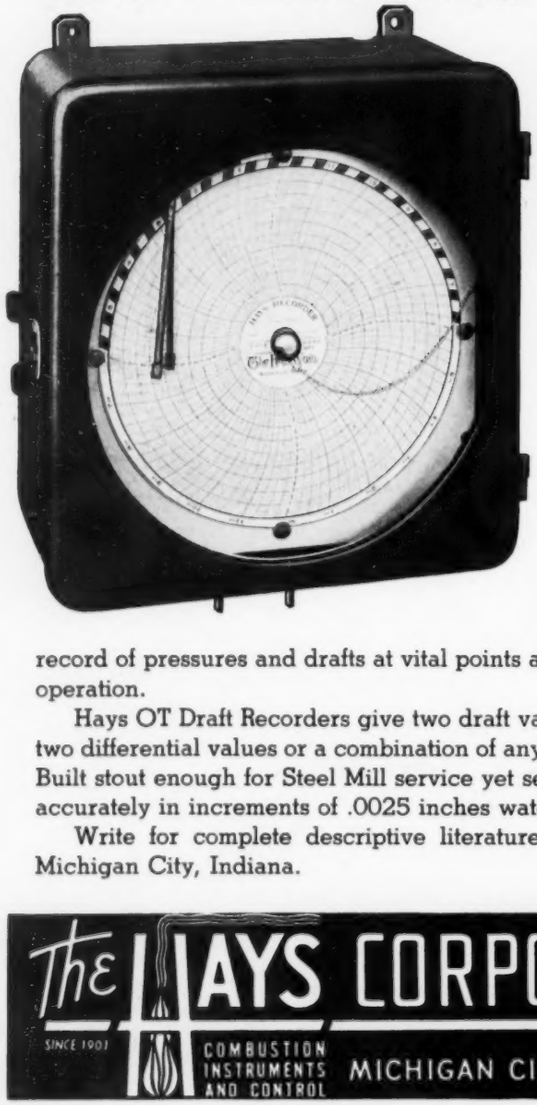
The external form of any motor is closely interwoven with the provision made in suitable openings for the entrance and exit of cooling air. In the new motor it was determined that these openings should be so located in the end shields and cast frame that there would be a greater degree of protection against the entrance of falling liquid or particles than existed in previous open motors. A goal was set of obtaining the greatest protection of these openings possible without interfering with ventilation. Efforts, therefore, were concentrated on improving the thermal capacity of the motors without reducing the space available for active materials. The use of Formex magnet wire was a long step in the achievement of the desired results. Its excellent insulating properties in addition to its toughness and resistance to heat and solvents make it an ideal material. Improved air deflectors and fan designs, in addition to double-end ventilation, contributed materially to lower motor temperatures. In the double-end system of ventilation, cool air—drawn into both ends of the motor—immediately impinges against the coil extensions, resulting in equally low temperature of these parts at both ends of the motor.

Large, integrally cast rotor fans draw ample, low-velocity air through openings in the lower portion of each end shield. Efficiency of cooling is increased through the use of large, smooth air passageways and baffles which control its direction, velocity, and discharge through openings in the frame just above the motor feet. The motor operates well within the standard 40 degree C. temperature rise.

So far as insulation is concerned, the new magnet wire, "Formex," which was developed by General Electric after 10 years of research, is used on all ratings of the new motor. Because of this tough, heat- and solvent-resisting magnet wire, it is now possible to eliminate largely the older type paper, cotton coverings, and other fibrous materials which absorb moisture and over a period of years deteriorate due to the effect of heat and chemical agents. Motor windings are further protected by the application of an improved synthetic-resin varnish and a covering coat of red. The result is a tough, space-saving motor insulation, highly resistant to heat, moisture, and mechanical abuse.

Make sure of **BALANCED**

DRAFT CONDITIONS IN



OPEN HEARTHS
•
SOAKING PITS
•
ANNEALING FURNACES
•
SLAG MILLS

GOOD furnace control requires an accurate record of draft, pressure or differential, as given by Hays Series OT Supersensitive Draft Recorders.

These instruments give a correct indication of furnace atmospheres and a permanent record of pressures and drafts at vital points as guides for most effective operation.

Hays OT Draft Recorders give two draft values, two pressure values, two differential values or a combination of any two of these three values. Built stout enough for Steel Mill service yet sensitive enough to register accurately in increments of .0025 inches water.

Write for complete descriptive literature to 955 Eighth Avenue, Michigan City, Indiana.

The HAYS CORPORATION
SINCE 1901
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A

STEEL FIRM IMPROVES PRODUCTION UNITS

▲ Allegheny-Ludlum Steel Corporation, Pittsburgh, Pennsylvania, has either completed, under way, or authorized, improvements in its main productive units during 1940, which will result in an increase of electric furnace melting capacity of approximately 50,000 tons of alloy steel annually.

The expansion program provides for a corresponding increase in finishing facilities, and affects each one of the company's plants or subsidiaries in Brackenridge and West Leechburg, Pennsylvania, Watervliet, Dunkirk and Buffalo, New York, Wallingford, Connecticut, and Detroit.

Also under active consideration at this time are additional plans for expansion of facilities, the details of which are not ready for announce-

ment yet, which would give Allegheny Ludlum a further material increase in capacity.

PROGRAM OF EXPANSION AIDS STEEL PRODUCTION

▲ An extensive program is being completed at the plants of the Timken Roller Bearing Company to provide for every possible contingency that might arise to cause interruptions in production of the large amount of defense work that is flowing through the company's plants. For several weeks engineers of the company have been making a comprehensive scientific survey of this subject in an attempt to foresee every possible emergency, and assure the continued rapid production of defense material without possibility of interruption. Several important installations of major pieces of equipment are now being made to accomplish this result.

Among these is the erection of a 200,000 gallon water tank to be used in addition to the present tanks as an emergency water supply in case of fire which might interfere with defense production. This tank which is being erected at a cost of $30,000, will be built 150 ft. high to provide a gravity water supply that will amply take care of the whole plant, and will function as a reserve supply against the possible failure of the company's own water pumping equipment. It is connected to sprinkling systems throughout the plant.

A heavy fuel oil system is also being installed at a cost of approximately $250,000 to assure the continued operation of equipment being used on defense work, in the case of possible failure of the natural gas supply which has been used heretofore. The installation will be completed early in January. This fuel oil system consists of a large "tank farm" comprising a central storage to accommodate 1,250,000 gallons of heavy fuel oil, sufficient for a month's capacity operation. As an additional precaution, provision is being made so that the fuel oil can be pumped direct from five freight cars at one time into feeder lines leading to two distributing tanks of 100,000 gallons capacity each, located in the central part of the plant. This "tank farm" is hooked up to the company's open hearth furnaces, billet heating furnaces, and soaking pits of the Canton plant. A separate unit is being installed at the Gambrinus plant.

Heavy fuel oil has to be heated to 250 degrees F. before it can be atomized and burned (it even has to be preheated to draw it out of freight cars, or for distribution into the feeder mains from the tanks), and the fire risk is thus so small as to be negligible. The company has gone so far as to provide protection for this also, and the installation is adequately protected with a complete fire-fighting system of its own.

REPUBLIC ACQUIRES TROY BLAST FURNACE PROPERTY

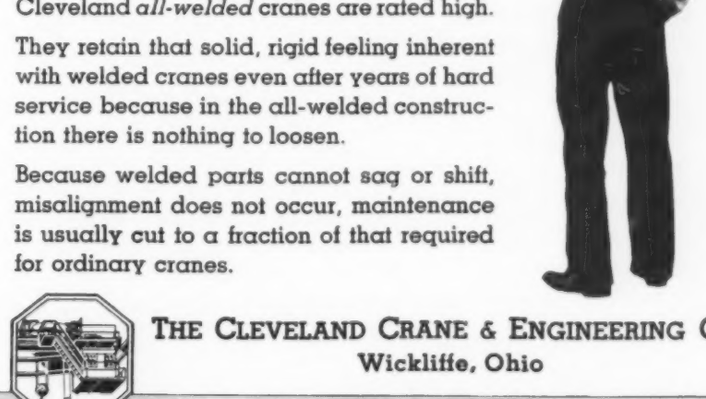
▲ Republic Steel Corporation recently acquired ownership of the blast furnace owned by the Hudson Valley Fuel Corporation at Troy, New York. The property, which includes 50 acres of land and necessary equipment, was first leased by Republic on July 9, 1940, after having been out of operation since December, 1938. The blast furnace has a 17 ft. 6 in. hearth

Two Cleveland all-welded magnet cranes in a modern mill. 10 ton, 100'-0" span crane in foreground. Other crane is 15 ton.

In mills where various cranes are used and where their merits can really be compared Cleveland *all-welded* cranes are rated high.

They retain that solid, rigid feeling inherent with welded cranes even after years of hard service because in the all-welded construction there is nothing to loosen.

Because welded parts cannot sag or shift, misalignment does not occur, maintenance is usually cut to a fraction of that required for ordinary cranes.



THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES

ALL-WELDED OVERHEAD TRAVELING CRANES

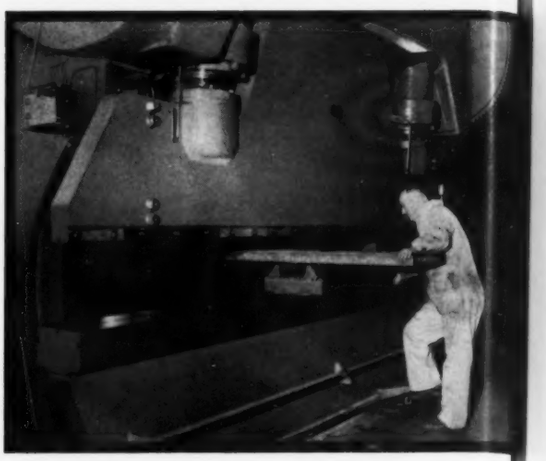
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

diameter and produces merchant grades of iron.

The furnace requires an operating force of 225 men who were employed by the former management and are residents of Troy. The blast furnace, which will use New York State materials entirely, was constructed in 1924 by the Troy Coke and Iron Company.

BENDING PRESS HAMMERS ARMOR PLATE TO SHAPE

▲ The necessity for straightening armor plate has created a new important job for bending presses in recent months. Upon heat-treating armor plate it becomes warped and must be hammered back to shape. Bending presses have been discovered as a fast economical method for performing this work.



Armor plate becomes warped upon heat treating, and must be hammered back into shape. The bending press shown above is capable of straightening armor plate 2½ in. thick and having a tensile strength of 170,000 lb. per sq. in.

The steelweld bending press, manufactured by the Cleveland Crane and Engineering Company, is capable of straightening armor plate 2½ in. thick and having a tensile strength of 170,000 lb. per sq. in. Dozens of presses have been purchased for this work. The machines usually run continuously 24 hours a day.

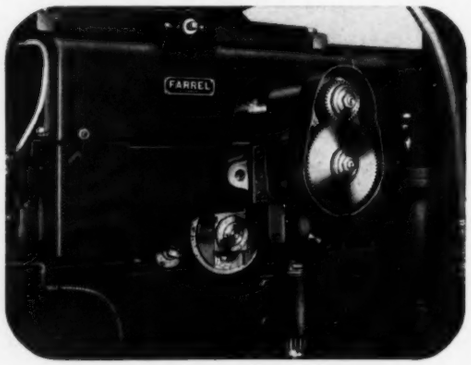
Tremendous power is required for plate straightening since the ram of the press hits at full tonnage capacity every stroke of the machine. One hundred or several hundred strokes are required as condition of the plate demands. Presses run at 20 to 40 strokes per minute, depending upon plate thickness.

MEET DEMANDS WITH NEW ADJUSTABLE SPEED UNITS

▲ To meet the demand for its all-electric, a-c. adjustable-speed drive in sizes which would extend this simple method of control to larger applications, particularly in the printing, textile and machine tool fields, than were contemplated when the system was first made available two years ago, Reliance Electric and Engineering Company is announcing three additional V*S units of 20, 25, and 30 hp.

The same principle of speed control is used as in the other sizes which range from one hp. upward. Only changes which have been made are concerned with the outward appearance of the unit. For the sake of compactness it has been mounted hori-

Accurate Roll Contour Assured by . . . .



Crowning and Concaving Device of

FARREL ROLL GRINDERS

Precise construction, which marks every feature in the Farrel Heavy Duty Roll Grinder, is based upon the principle of "maximum transfer of skill to mechanism."

The patented Farrel crowning and concaving mechanism with which Farrel Roll Grinders are equipped, produces a mathematically accurate curve of correct shape for a crowned or concaved roll, exactly symmetrical on both halves of the roll. The same setting invariably produces precisely the same contour, which permits fixed uniformity in all rolls.

The mechanism is the adjustable, single eccentric type, readily accessible so that settings for any curve can be made quickly. Its in-built location on the rear of the carriage gives firm support to the wheelhead and prevents any tendency to vibration at this point.

This and other features of the Farrel Heavy Duty Roll Grinder provide assured control of roll accuracy and finish to predetermined standards and reduce dependence upon the skill of the operator to a minimum. "Production with Precision" is built into every individual part of the Farrel Roll Grinder.

For complete information write for copy of Bulletin No. 111.

FARREL FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

zontally instead of vertically as in the smaller sizes. Particular attention has been given to the design of the mounting brackets which contain special longitudinal rubber shock pads to insure quiet operation of the unit, wherever it may be installed in the shop. No special foundation or leveling is required.

Three wires from the 3-phase, 60-cycle, a-c. power source (which may be 220, 440, or 550 volts) are connected to the control unit exactly as would be done with any motor and control. From the control unit, secondary circuits are run to the other three elements of the drive, namely, the driving motor, speed adjuster, and start-stop push button station. Both the speed adjuster, which is no larger than an ordinary plate rheostat, and the buttons for starting and stopping the driving motor, can be located anywhere on the machine the operator may find it most convenient to reach.

The driving motor is designed particularly for adjustable-speed service. It can be supplied in a variety of types, including enclosed fan-cooled, splash-proof and explosion-proof. Gear-motors may also be used. Connection to the driven machine is by any one of the methods regularly used for direct motor drives. Considerable space is saved because no intermediate devices are required for the speed changing.

The motor can be started and stopped without interfering with the speed setting. Moreover, the speed can be changed while the motor is in operation. Quick stopping is obtained by regenerative braking. No clutches of any description are needed since ample torque with controlled acceleration has been provided for all starting conditions.

Regardless of size, these adjustable-speed drives not only make very slow speeds available for such operations as threading material or setting up work, but provide an almost infinite number of speed variations within an over-all speed range of 16 to 1 for continuous 24-hour duty.

DEVELOP SEALING COVER FOR FLUORESCENT LAMPS

▲ New "Sealed-Flo" units featuring a new sealed cover construction which protects the fluorescent lamps and reflecting surfaces from dust and dirt, thus reducing cleaning and maintenance costs, were announced by the Benjamin Electric Manufacturing Company. This new development extends the use of fluorescent lighting to locations requiring vapor-proof and dust-tight fixtures, opal glass diffusing fixtures or "unbreakable" glass protection of lamps and reflecting surfaces.

Through these new units, the advantages of fluorescent lighting for both general and localized illumination can now be provided for locations where lighting equipment is subject to even the most adverse atmospheric conditions such as steam, dampness, non-combustible dusts and vapors. These units provide high levels of glareless light with softly luminous shadows, and are rated as vapor-proof by the Underwriters' Laboratories.

The new protective cover with which the one piece units are equipped is specially constructed to provide for easy servicing. The cover is hinged to the lamp housing and locked in place by means of hand operated cover clamps.

When overloads are imperative...

CHINALAK

will keep motors running

Today, more than ever before, motorized equipment is being subjected to overload . . . production schedules must be maintained . . . motors must not fail.

Many companies are turning to glass insulation to enable their motors to operate at high temperatures. If this is done, care should be taken to see that the insulating varnish used over this glass insulation offers maximum flexibility. A varnish that will crack and flake off at elevated temperatures leaves the motor windings unprotected and defeats the purpose of the glass insulation.

DOLPH'S CHINALAK Black Baking Varnish has proven its adaptability to glass insulated motors. It remains flexible even when subjected to the higher temperatures often encountered in glass insulated motors. Comparative tests have shown it to be far more flexible than many leading baking varnishes . . . 250% more flexible than insulating varnish "A" . . . 100% more flexible than "B."

Complete details regarding this remarkable insulating varnish are available without obligation. Simply send us the name of the engineer in your plant who is responsible for motor maintenance. We will see that he receives full information.

JOHN C. DOLPH CO.

Insulating Varnish Specialists

166A Emmett Street Newark, N. J.

REPUBLIC WILL ADD TO ARMOR PLATE CAPACITY

▲ Republic Steel Corporation will make a substantial addition to the nation's light armor plate capacity in Massillon, Ohio, and will go into partial operation early in the year.

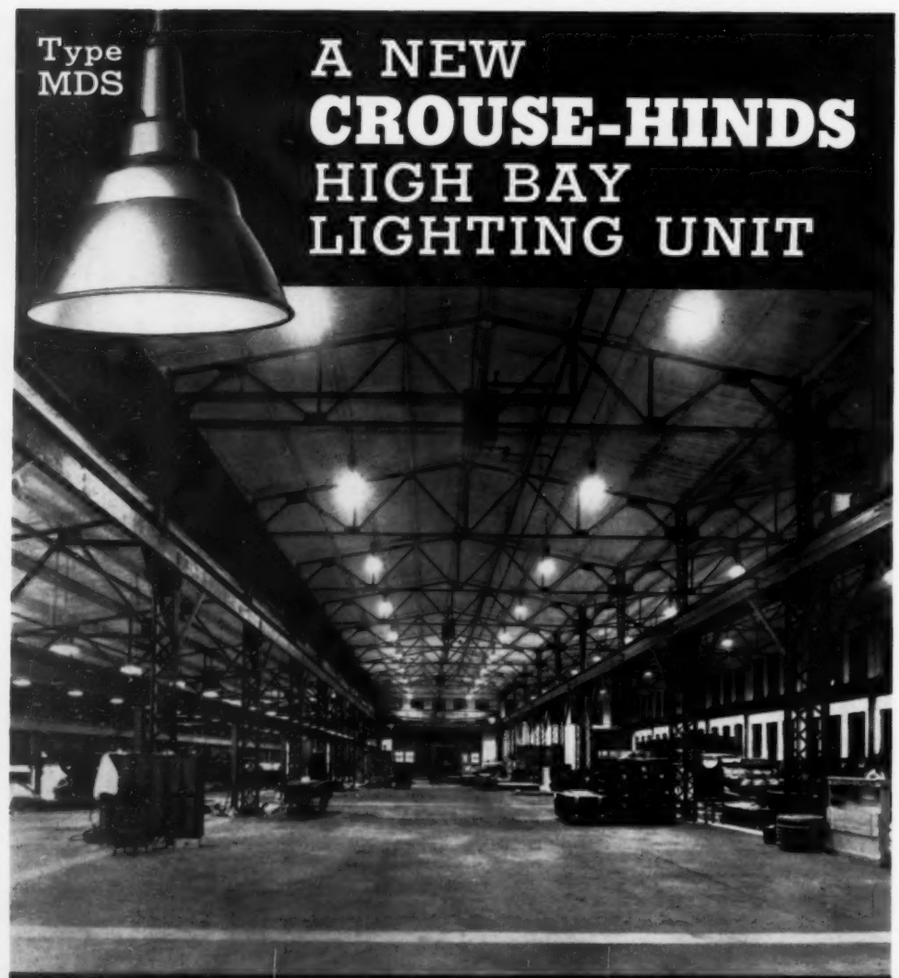
The new mill will absorb the three sheet mill buildings, having a total of nearly 300,000 sq. ft. of floor space.

The corporation will begin immediately to install equipment for heat treating and cutting, finishing and shaping armor plate. The ultimate capacity of the plant will be reached by late summer.

The first installation will consist of 18 new heating furnaces to supplement existing furnaces, presses for straightening the armor plate after it has been heat treated, and equipment for shaping it.

Electric furnace steel for the armor plate mill will be produced in Republic's Canton electric furnace plant, for which the sixth 50-ton electric furnace has recently been ordered.

It is understood that the contract for 18 heating furnaces has been awarded to the Surface Combustion Corporation.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A NEW
CROUSE-HINDS
HIGH BAY
LIGHTING UNIT
A Good Example of Modern Steel Plant Lighting
A high bay area lighted with Crouse-Hinds type MDS high bay lighting units equipped with 400-watt mercury vapor lamps.
Write to the Illumination Dept. and a Crouse-Hinds representative will gladly assist in solving your lighting problems.
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CROUSE-HINDS COMPANY OF CANADA, LTD., Main Office and Plant: TORONTO, ONT.

DESIGN NEW CUTOUTS FOR LIGHT AND HEAVY DUTY

▲ Designed for light and medium duty service on distribution lines and substations operating at 2300–13200 volts, new, compact cutouts and reclosers are announced by Schweitzer and Conrad, Inc.

An important feature of these cutouts is the provision for complete, positive separation of the arcing terminals. The flexible cable of the link is pulled straight out of the tube to clear arcs quickly, even in case of low fault currents. A toggle action releases and drops the fuse tube open after the fault is cleared, plainly indicating the blown condition.

Reclosers are made up of two or three of the single cutouts with the addition of automatic circuit-reclosing parts. Thus it is possible to convert a single cutout into a two-shot or three-shot recloser with ease. All parts are finished, drilled, tapped to make these conversions and assemblies possible in the field.

All types are furnished for three voltages: 5000, 7500/12500, and 15000. Fuse tubes are rated at 100 amperes and may be fused with fuse links. The short circuit interrupting capacities meet NEMA standards.

A-C. CONTACTORS OFFER REMOTE CIRCUIT CONTROL

▲ The new line of motor controls, made by the Colt's Patent Fire Arms Manufacturing Company, includes the magnetic a-c. contactors, general purpose alternating current contactors, furnished in sizes 0 and 1. They provide a safe and convenient method of remotely controlling electric circuits from one or more push button stations or pilot devices. The contactors are horse power rated for motor control and can be employed where overload protection is not required or is otherwise provided for. They are suitable for handling single phase or polyphase a-c. motors, or for use as flexible relaying devices

for control systems such as are used in machine tools, switchboards and special control panels.

An important feature of the magnetic contactors is the 3-point ball bearing suspension of the movable electro magnet assembly, reducing friction to a minimum and guiding contacts into correct alignment.

WEIRTON STEEL TO BUILD BLAST FURNACE

▲ Weirton Steel Company has announced construction of a new blast furnace and additional coke ovens that will add approximately 300,000 tons to the annual pig iron capacity of that company. This program will be in addition to the rebuilding and enlargement of blast furnaces in other National Steel Corporation plants at Detroit and Buffalo. The improvements at the three plants, which will cost about $15,000,000, will increase the annual pig iron capacity of the National Steel Corporation by approximately 700,000 tons.

The expansion of blast furnace facilities has been undertaken because of the increased demand for steel products that is resulting from the war overseas and the defense program and also becuase of the shortage in steel scrap which must be replaced with pig iron.

Without additions to primary steel producing facilities, the new pig iron capacity will make possible a substantial increase in the production of steel ingots with existing equipment.

In addition to the blast furnace and auxiliary equipment, the Weirton Steel Company program will include the construction of 45 coke ovens, extension of the ore yard, extension or construction of a number of plant buildings, and installation of cranes, power lines and other types of equipment.

Company officials expect the new facilities to be ready for operation late in 1941. According to preliminary estimates, the program will increase the Weirton Steel Company's pig iron and coke capacity by more than 40 per cent and will add approximately 240,000 tons per year to ingot capacity.

Also under way at the Weirton plant is reconstruction of a semi-continuous strip mill so that it may be utilized for the production of either strip steel or structural shapes. This will give the Weirton Steel Company three mills, with a total capacity of 600,000 tons per year, with which to meet the growing demand for structural steels that has resulted from the defense program.

CENTRAL STEEL ERECTS MODERN BUILDING

▲ Central Steel and Wire Company has started construction of new facilities at a cost of $500,000. These will comprise a one-story warehouse building of 120,000 sq. ft. and costing $375,000, and a one-story office of 25,000 sq. ft. and costing $125,000. Completion is scheduled for March 15.

NEW LITERATURE

▲ Cutler-Hammer, Inc., has issued a book describing "Unitrol," a new unit type of standardized motor control construction. An attempt has been made to anticipate all of the questions which steel men might ask regarding this important Cutler-Hammer development.

Executives who are desirous of keeping in tough with the latest developments should write to Cutler-Hammer, Inc., in Milwaukee, Wisconsin, and request this book.

▲ Allis-Chalmers Manufacturing Company has published a bulletin on the new all-in-one "Electrifugal" pumps for 1 to 10 hp., inclusive, for heads up to 160 ft. It profusely illustrates and describes the unit construction, incorporating either special splash-proof motors, totally enclosed, fan-cooled motors, or explosion-proof, fan-cooled motors as may be required.

Bulletin B-6140 may be obtained by writing to the Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.

▲ Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania, has available the following catalogues:

(1) Booklet No. F-8500. A new four page booklet describing a twin lamp fluorescent RLM type luminaire, designed especially for general or supplementary lighting in low bay industrial areas. The booklet contains a complete description of the fixture, including spread and cut-off values, and its operating power factor.

(2) Catalogue No. 30-000. The new 64-page enlarged edition of the "Quick Selector" catalogue. This is second edition of this catalogue that is published twice yearly, and prepared especially to facilitate the user of electrical equipment in selecting the correct apparatus for any motor, lighting, or feeder circuit.

▲ C. M. Kemp Manufacturing Company has published a bulletin on "Series T Industrial Carburetor." This booklet describes in detail the Kemp method of 100 per cent premixing of gas and air giving accurate heat control, wide turn-down range, flame pressure for restricted burner areas, flexibility of flame characteristics from reducing to oxidizing, carbon monoxide elimination and complete combustion efficiency.

Charts, dimensions, and installation plans are included in this booklet, copies of which may be obtained by writing to the C. M. Kemp Manufacturing Company, 405 East Oliver Street, Baltimore, Maryland.

▲ Trumbull Electric Manufacturing Company has just published the second 1940 issue of the "Trumbullist." This catalogue describes the various electrical control equipment manufactured by this company.

Copies of the "Trumbullist" may be obtained by writing to the Trumbull Electric Manufacturing Company, Plainville, Connecticut.

▲ Brown Instrument Company has issued a brochure entitled "Thermometers and Pressure Gauges." Amply illustrated with actual applications of various equipments manufactured by this company, the book contains detailed descriptions of these applications.

Copies may be obtained by writing to the Brown Instrument Company, Wayne and Roberts Avenues, Philadelphia, Pennsylvania.

▲ Elwell-Parker Electric Company has published a book describing seven typical steps common to most industries, and each a spot where waste may occur in materials handling. From incoming car to the receiving department; receiving to storage; storage to processing; through the processing department; into storage; from storage to packing, and then into the outgoing car or motor truck, are the seven steps.

The bulletin, "How to Save Money Handling Your Loads," may be obtained by writing the Elwell-Parker Electric Company, 4190 St. Clair Avenue, Cleveland, Ohio.

ITEMS OF INTEREST

E. G. Hill has been promoted to the assistant general superintendent's post at the Gary Works of the Carnegie-Illinois Steel Corporation, succeeding S. M. Jenks, who was recently advanced to the general superintendency. Mr. Hill joined the corporation in 1938, when he was placed in charge of research at the Gary Works. Since then he has served as assistant to the general superintendent in charge of technological coordination. Prior to his corporation association, Mr. Hill had been professor of metallurgy at the University of Pittsburgh, from 1920 to 1930, and subsequently in research work for the Mellon Institute, and also director of research of the Lukens Steel Company.

Jacob J. Phifer was appointed assistant general superintendent of the Fairfield steel works of the Tennessee Coal, Iron and Railroad Company, Fairfield, Alabama. Mr. Phifer, a native of Allentown, Pennsylvania, was born December 4, 1898. He has been with the United States Steel Corporation since February 1, 1920, when he entered the employ of the American Steel and Wire Company as a machinist at that company's Allentown Works. He went to the Tennessee company January 1, 1937, as assistant superintendent of the Fairfield wire works, becoming superintendent of that division in July, 1938.

Marion G. Crosthwait has been named superintendent of the Fairfield wire works of the Tennessee Coal, Iron and Railroad Company, Fairfield, Alabama. Mr. Crosthwait was born in Birmingham, Alabama, December 18, 1896. He entered the service of the United States Steel Corporation, March 16, 1920, as a draftsman at the Fairfield Works of the American Steel and Wire Company. He became head draftsman in January, 1923, continuing in that position after the Fairfield operation was taken over by the Tennessee company in 1933. He was promoted to assistant superintendent of the wire works in September, 1939.

Arthur D. Beers, chief metallurgist at Gary Works of Carnegie-Illinois Steel Corporation, for the past three years, succeeds E. G. Hill as assistant to the general superintendent in charge of technological coordination.

R. T. Johnson, who has been associated with the Pittsburgh office of the Electric Controller and Manufacturing Company for the past 23 years, has resigned. Mr. Johnson and **J. B. Laird** have formed the Laird-Johnson Company, sales representatives, with offices at 547 Union Trust Building, Pittsburgh, Pennsylvania. This new company will handle the following manufacturers' equipment: Northern Engineering Works—manufacturers of electric overhead traveling cranes and electric hoists; Hill-Acme Company—manufacturers of alligator shears and special machinery; and Watson-Stillman Manufacturing Company—manufacturers of hydraulic presses, machinery and jacks.

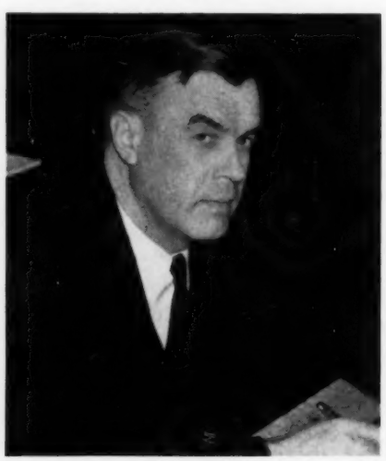
Harry A. Strain, for the last four years assistant general superintendent of the Carnegie-Illinois Steel Corporation's South Chicago works, was appointed director of raw materials, fuel and power. Mr. Strain began his association with the United States Steel Corporation subsidiaries in 1905 as a clerk employed in the auditing department of the American Steel and Wire Company at Joliet. His actual iron and steel making experience began one year later at the blast furnaces at Joliet. He has been employed at the South Chicago works continuously for the last twenty years, with the exception of one year spent as superintendent of blast furnaces for the Woodward Iron Company.

Mr. Strain has been assistant general superintendent of South Works since January, 1936. He is a native of Clinton, Illinois, and received his technical education at the Armour Institute of Technology.

Charles W. Cristal has been appointed sales manager of the electrical construction department of the Dingle-Clark Company, contracting engineers with headquarters in Cleveland, Ohio. Mr. Cristal is a graduate of the United States Naval Academy and of

E. G. HILL

J. J. PHIFER



M. G. CROSTHWAIT

R. G. GLASS

M. J. DEVANEY

M. F. YAROTSKY

the Massachusetts Institute of Technology and brings to his new connection seventeen years of varied experience in the electrical industry.

Robert G. Glass has been appointed assistant manager of operations, Carnegie-Illinois Steel Corporation, Chicago district. Mr. Glass, who for the past four years has been assistant to manager, is a graduate of the Ohio State University. He first secured employment as a transitman for the Baltimore and Ohio Railroad in 1906. Two years later he was made assistant engineer of the railroad at Baltimore, Maryland, and in 1911 was appointed division engineer at New Castle, Pennsylvania. He has been connected with the United States Steel Corporation subsidiaries since 1912, when he started as assistant inspection engineer. He was assistant manager of the department of metallurgy and inspection from 1923 until his appointment as assistant to manager of operations in 1936.

M. J. Devaney was appointed assistant general superintendent at Carnegie-Illinois Steel Corporation's South Works, Chicago, Illinois, succeeding H. A. Strain. Mr. Devaney has been continuously associated with the South Works for the last forty years. He started April 28, 1900, as a signal boy on the plant docks and advanced through various positions to his most recent post of division superintendent of steel production.

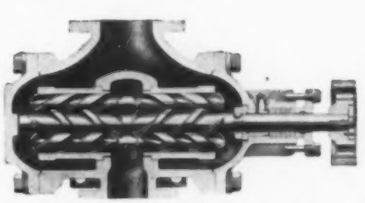
Michael F. Yarotsky succeeds M. J. Devaney as superintendent of steel production at the South Works of the Carnegie-Illinois Steel Corporation, South Chicago, Illinois. Mr. Yarotsky, who has been assistant superintendent of steel production at the South Works, in turn, is succeeded by **George E. Gustafson,** who has been associated with the South Works for the last 33 years and recently has been serv ng as superintendent of No. 2 open hearth. Mr. Gustafson is succeeded in the open hearth position by **Howard A. Parker,** who has been serving as assistant superintendent. Mr. Parker is succeeded by **George W. Bruce.**

George A. Bryant, executive vice president and general manager of the Austin Company, Cleveland, Ohio, since 1930, has been elected president and general manager of this national engineering and construction organization, succeeding the late W. J. Austin.

Mr. Bryant, a native of Chicago, received his engineering education at the University of Illinois and first became associated with the Austin Company as a field

IMO can do it!

Because the majority of purchasers of *De Laval-IMO ROTARY PUMPS* for fuel oil and lube oil service have come back with repeat orders, we know IMO can do your job better too. Our recommendations will cost you nothing and probably will save you money in the end. Ask for Catalog I-53.



DE LAVAL STEAM TURBINE CO., TRENTON, N. J.

engineer 27 years ago on a building job near Medicine Hat, Alberta, Canada. In 1916, he was named district superintendent for all Austin operations in New England, and shortly thereafter became manager of the company's Philadelphia office. In 1917, Mr. Bryant was directing all Austin operations throughout the east. Later, in 1918, he was made general sales manager for the entire country, which responsibility he carried until early this year.

H. W. Young, president of Delta-Star Electric Company, Chicago, and **L. E. Messinger,** president of Canadian Line Materials, Ltd., Scarboro Junction, Canada, announce the association of their respective companies for the exclusive manufacture of Delta-Star equipment in Canada.

Because of a number of contracts, both domestic and foreign, the Arthur G. McKee and Company, 2300 Chester Avenue, Cleveland, Ohio, contemplates adding to the engineering staff to fill vacancies created by promotions within the organization. Such additions would include designers, checkers, squad leaders, and technical assistants. **Stephen A. Derry,** director of the Derry Plan for Cooperative Placement, 872 Hanna Building, Cleveland, has been appointed employment director for the Arthur G. McKee and Company, and has opened his offices in the McKee Building to interview and select qualified engineers and designers.

Among the foreign contracts held by Arthur G. McKee and Company is the complete supervision of the design work of a steel plant to be built in Rio de Janeiro, Brazil. The Brazilian steel plant will be built by the Commissao Executiva Siderurgico Nacional near Rio de Janeiro. It will include coke ovens, a 1000 ton blast furnace, open hearth furnaces, and various types of rolling mills for the production of a complete range of semi-finished steel, rails, structural, sheets, tin plate, and other materials.

S. A. DERRY

To be added to the McKee staff are 50 men for general steel plant layout, 100 for concrete reinforcing and structural work, 25 mechanical and electrical engineers, and 25 technical specialists.

D. C. Mills has been appointed assistant to W. F. Ames, manager of compensation and safety, Bethlehem Steel Company, Bethlehem, Pennsylvania. Mr. Mills, whose title will be assistant manager of compensation and safety, is a graduate of United States Naval Academy, class of 1923. He subsequently studied law at the University of Maryland, and was admitted to the Maryland bar. Entering the employ of Bethlehem Steel Company upon his graduation from the Naval academy, Mr. Mills completed the loop course and was assigned to Maryland plant, Sparrows Point, where he held successively the positions of assistant master mechanic in the rail mill, general foreman on construction, and plant steam engineer.

In 1939 he was transferred to Bethlehem and assigned to duties in the office of the manager of compensation and safety.

Fred R. Davis, 64, a founder of the Audit Bureau of Circulations and employed as assistant advertising manager of the General Electric Company for the past 35 years, died recently. Mr. Davis was born in Adams, Massachusetts, attended Union College in Schenectady, and was graduated from Worcester Polytechnic Institute with the degrees of B.S. and M.S. in engineering. In 1901, he entered the General Electric organization as a test student and in 1902 went to Fort Wayne, Indiana, as publicity manager of the Fort Wayne Electric Company. In 1905 he joined the advertising department of the General Electric Company in Schenectady.

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